NEW SOUTH WALES.

DEPARTMENT OF MINES.

GEOLOGICAL SURVEY.

E. F. Pittman, A.R.S.M., Government Geologist.

MINERAL RESOURCES

No. 17.

REPORT

ON THE

COBAR COPPER AND GOLD-FIELD.

Part I.

BY

E. C. ANDREWS, B.A., F.G.S.,

Geological Surveyor.

1911.

SYDNEY: W. A. GULLICK, GOVERNMENT PRINTER.

1913.

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Frontispiece

Photo Great Cobar, Ltd.

Cobar Mining District, South of Great Cobar Township and Mine.
Cobar to Mount Nurri, 21 miles

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Department of Mines,
Sydney, 17th January, 1913.

Sir,

I have the honor to submit for publication No. 17 of the Mineral Resources Series "Report on the Cobar Copper and Gold-field," Part I, by Mr. E. C. Andrews, B.A., Geological Surveyor.

As the most important copper and gold producing district of the State at the present time, Cobar is well worthy of the careful examination and detailed description which Mr. Andrews has undertaken, and it will be found that he has condensed in the following pages a very large amount of interesting information which will be appreciated by geologists and mining engineers alike.

I have the honor to be,
Sir,
Your obedient Servant,
EDWARD F. PITTMAN,
Government Geologist.

The Hon. Alfred Edden,
Minister for Mines.

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INTRODUCTION.

Instructions.

In 1910 the writer was instructed to make a geological survey of the Cobar Copper and Gold field, by Mr. E. F. Pittman, A.R.S.M., Under Secretary and Government Geologist to the Mines Department.

Field and Office Work.

The field work occupied the latter half of the year 1910, and also a portion of 1911. The report was completed in 1912.

During the month of January (1911), the writer was absent on leave for three weeks.

During the period, 21st June to 16th December, 1910, the writer was accompanied by Mr. C. E. Murton, Field Assistant. Mr. Murton, among other duties, mapped in the alluvium as shown on the map, and prepared the lists of mineral products supplied in the report.

Acknowledgments.

At the outset, the writer desires to place on record the great help he has received in the preparation of this report from the "Copper Mining Industry of New South Wales," by Mr. J. E. Carne, F.G.S., Assistant Government Geologist. Numerous extracts have been reproduced from his book.

For the fossil determinations, the writer is indebted to Mr. W. S. Dun, Palæontologist to the Geological Survey. The writer desires also to cordially thank Mr. G. W. Card, A.R.S.M., Curator of the Departmental Museum, for the list of rock determinations, for petrological notes, and for the preparation of the micro-photographs accompanying the petrological descriptions.

For the careful rock and mineral analyses accompanying this report and carried out at the Departmental Laboratory, the writer is indebted to Mr. J. C. H. Mingaye, F.C.S., and also to Messrs. H. P. White, W. A. Greig and G. W. Stone, who carried out analyses under the supervision of Mr. Mingaye.

The photographic illustrations were prepared by the Government Printer, Mr. W. A. Gullick, while plates Nos. 25, 26, and 27 were drawn by Mr. P. T. Hammond.

Special attention is drawn to the great obligations under which the writer is due to the various mining officials, without whose cordial co-operation the present report would not have been possible. Every facility was extended to the writer in the matter of examination of the various mines, and permission to reproduce plans and sections of the mines was given without reserve. Special thanks are due to Mr. H. C. Bellinger, General Manager of the Great Cobar Mining Company; to Mr. John Leah, Legal Manager of the Occidental and Great Cobar North Mines; to Mr. A. E. Moore, Legal Manager of the Queen Bee and Gladstone Mines; to Mr. L. V. d'Apice, Western Lands Surveyor; to Mr. John Polkinghorne, Inspector of Mines; and to Mr. S. M. Cummins, District Works Engineer, for showing the writer numerous places of geological interest in the district; to Mr. N. Treloar, Mr. Murphy, Mr. A. W. Hudson, Mr. A. E. Strick, Mr. A. P. Penman, and Mr. A. J. Lindsay, of the Great Cobar, the writer is deeply indebted for their invaluable assistance in the matter of securing metallurgical and mining information at the Great

Cobar. From Mr. E. C. Delohery, Manager of the Great Cobar North, Mr. John Davies, Manager of the Occidental, Mr. Thomas Lean, of the Occidental, Mr. Winton, Manager of the Cobar Gold-mine, Mr. Williams, Manager of the Chesney, Mr. Peter Snelson, Mr. John Woolcott, Mr. T. E. Farquhar, Mr. C. R. Mackenzie, Manager of the C.S.A. Mine, and from Mr. G. Dunlop, of the Queen Bee Mine, the greatest assistance was obtained in the matter of mine examinations—to all these workers the writer desires here to express his cordial thanks; as also to Messrs. W. J. Cornish, Neil Morrison, and Frank Lean, for notes on the history of the field.

The maps and sections illustrating the report were prepared by Mr. O. Trickett, L.S., and the photographic blocks have been reproduced from photographs and negatives supplied by the Great Cobar (Limited), Mr. Thomas F. R. Lean, Mr. C. E. Murton, and Mr. M. Sullivan. To all of these the sincere thanks of the writer are here tendered.

The reports of Messrs. John Polkinghorne, R. Schloesser, D. Milne, and J. R. Godfrey, Government Inspectors of Mines, have been freely used in the preparation of the report.

SUMMARY OF RESULTS.

General Geology.

Lack of exposures.—Cobar lies upon a plain of denudation. The extreme vertical relief of the area mapped (about 500 square miles) is 500 feet. This occurs as a rough rocky knob and narrow ridge, 20 miles south-east of Cobar itself. Elsewhere the greatest height above the plain is less than 200 feet. The waste sheet is so constant a feature that no natural sections occur in the area. Even the broad and shallow valleys which give an undulating appearance to the plain have been alluviated in recent geological time. The detailed working out of the stratigraphical succession in such a region was found to be practically impossible, and, in fact, only a few points in the geological history have been satisfactorily explained.

Sedimentary rocks.—The oldest rocks in which fossils have been distinguished in the district are the Cobar series. The rocks of this division embrace conglomerates, bedded limestones, quartzites, sandstones, cherts, and shales of Silurian age. No reliable estimate of the thickness of the beds could be made, but it is large. Sandstone and slate occupy the more western portion of the beds, while conglomerates, schistose slates, and limestones occur in the more easterly portion. To the west of the township of Cobar occurs an enormous thickness of quartzites, sandstones, claystones, and shales to which the name Amphitheatre series has been assigned. Its age is Devonian. The thickness of the beds is enormous, and appears to exceed 15,000 feet. Isoclinal folding may be responsible for this thickness by causing a doubling or even a greater multiplication of the beds. The evidence of heavy faulting in the region of the lode formations also suggests the probability of the duplication of the rock members farther west.

A difficult group of rocks to place in the stratigraphic sequence is the zone of altered sandstones. conglomerates, and slates in which the lodes are contained. The strike of this zone is roughly N. 30° W.; it never exceeds a width of 3 miles. The alteration products such as highly cleaved slates and sandstones, and sheared conglomerate pebbles, are never found at a great distance from the lodes, the cleavage dies out gradually into the country, and in the Cobar area this peculiar rock group cannot be traced north and south of the lodes. Heavy quartzite conglomerates, argillaceous sandstones, and slates are included. So far as they can be ascertained they represent a belt of altered Silurian strata.

No unconformity has been discovered between the Silurian and Devonian sediments, but the eastern Silurian members appear to have been thrust over and against the western rocks. Such heavy thrusting movement appears to have taken place during the mountain-making period which closed the Devonian period in this area.

Igneous rocks.—The only igneous rocks exposed in the whole of the Cobar district are two small volcanic rocks or pipes of orthoclase porphyry, distant 13 and 14 miles respectively from Cobar, in a S.S.E. direction. The pipes are about 250 yards in length, and about 75 yards in extreme width. In plan they are spindle-shaped. Such absence of igneous rocks just noted in an important copper-field is all the more striking because of the enormous denudation to which the district has been subjected since the close of the mountain-making period to which the intrusion of the "pipes" appears to be referable, for if igneous rocks had been associated with the lodes the removal of the mountain range should have revealed them in some measure.

Earth movements.—The Silurian sediments are more folded than the Devonian, and a period of compressive action thus is indicated for the close of the Silurian. The Devonian closed with a strong compressive force during which shearing and overthrusting took place.

Earth movements in the Cobar district, later than the mountain-making period just referred to, have been confined to minor oscillations in a vertical direction.

The Plain of Cobar.—This feature is due in all probability to the erosive activities of much later geological time. The broad shallow valleys with which the old plain of erosion has been diversified, are due to stream action on the plain at a time when the rainfall was more plentiful than at present. The rainfall of the present day is insufficient to keep the channels open and the valley bases are occupied by broad shallow belts of alluvium over which the flood-waters pass towards the Darling River.

The Copper Deposits.

Cobar district contains many ore deposits, the principal minerals won being copper and gold. Silver and lead also are obtained in subordinate amounts. The copper deposits are the most important in New South Wales, and equal, or even exceed, in importance the famous Mount Lyell and Mount Morgan lodes, situated in Tasmania and Queensland, respectively.

Production and Development.

Copper.—The ore deposits were discovered in 1869, and the first load of copper was despatched in 1871. For many years the development of the lodes was slow because only rich ores could be sent away, the Cobar district being far distant from established lines of communication. Since the extension of the railway to Cobar, however, the progress of the district has been very rapid, although the ore raised at the present time is of low grade. A strong company, the Great Cobar, Limited, has secured control of the principal mines of the district. The Great Cobar copper-ore bodies themselves consist of three large basic lenses of chalcopyrite in a pyrrhotite and magnetite gangue in which, however, are considerable admixtures of slate and quartz. In 1904, the Great Cobar Syndicate acquired the acid-ore body of the Chesney Lode. During 1906, these mines passed into the hands of the Great Cobar, Limited, which in 1910, secured control of the large acid-ore body (gold quartz) of the Cobar Gold Mines. This Company also owns the important gold-mines of the Peak. Large smelting works have been erected and electrolytic copper is producted. The Budgery, Mt. Boppy, C.S.A., Gladstone, Young Australian, Tharsis, and Tinto copper ores have all been smelted by the Great Cobar Company.

The approximate total production of copper for the district, up to the end of 1911, was :—

Great Cobar (Limited) ... ... (Inclusive of Chesney since 1904.)	92,000	tons.
Queen Bee	3,000	,,
Total	†95,000	tons.

Gold and silver deposits.—The principal metal mined in the district is copper, but the gold and silver values won are also considerable. The latter occur mainly in quartz veins and associated with chalcopyrite, iron pyrites, pyrrhotite (magnetic pyrites) galena and zinc-blende. The main producers* are the Occidental, Great Cobar, Chesney, Cobar Gold and the Peak Mines.

The Occidental was taken up as the United in 1871, the Chesney was prospected the same year, but not worked until 1887. The rich irregular gold shoots of the Peak were also found about the same year. The Cobar Gold Mines (Old Fort Bourke) were worked in 1887.

Lodes.—The general strike of the Cobar lodes is about North 15° to 20° West, and they occur as siliceous or ferruginous gossans arranged along parallel lines of weakness in the Palæozoic rocks. The mountain ranges, in which the lodes were formed at the close of the folding phase, have been completely removed, leaving only a monotonous plain of erosion. The horizontal section thus produced is a chance one so far as the lodes themselves are concerned, and some very important lessons may be deduced from a study of the known distribution of the lodes in space, when such distribution is considered in connection with the great erosion in the district; an erosion amounting to many thousands of feet. Thus, at first glance, the lodes appear to be arranged somewhat *en echelon*, each group with progress northwards having a tendency to lie west of that immediately to the south. Upon examination, however, it is found that the lines of weakness along which the lodes have been formed exist, in places, as definitely parallel zones, thus excluding all idea of the formation of the lodes *en echelon* by a process of repeated faulting to the west of a once-continuous vein. Nevertheless, the main payable portions of the veins do occur in this peculiar manner. In plan they are lenticular, and most probably also (as will be shown later) in longitudinal and transverse section. Some of the examples, such as the three large lenses of the Great Cobar, outcropped as ferruginous masses which gave little indication of the great size they attained at a depth of from 500 to 900 feet below the surface. At a depth of 1,250 feet they are still about as large in area as at any of the upper levels. Others, such as the Occidental, Chesney, and Cobar gold lodes outcrop as long lenses of siliceous gossan arranged along one line of weakness, the lodes being easily located by means of slight eminences, upon the western sides of which they outcrop. In general the lenses vary so little in width with increasing depth that no fears need be entertained of their non-continuance to depths considerably greater than the lowest levels worked to-day.

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* The Mount Boppy Mine, 25 miles east of Cobar, is the most important individual gold deposit in New South Wales. The present survey, however, does not include Canbelego.

† The total copper yield now exceeds 100,000 tons.

A curious feature is the decided relative basicity of the more westerly lodes, and the relative siliceous nature of the eastern examples. This eastern and western division into siliceous and basic ore bodies respectively might by some be considered as a southern and northern division. It is interesting in this connection to note that the basic western masses lie wholly in slates and claystones, while the siliceous eastern bodies occur at the contact of slates and sandstones.

The lodes may be divided again into two types, those which are characterised by development of chalcopyrite and pyrrhotite, and those characterised by presence of iron pyrites galena, and zinc-blende. The pyrrhotite veins have no defined walls, but appear to be cemented into the country, while the pyritic lodes have walls much more clearly defined and are generally younger than the bodies containing pyrrhotite.

The C.S.A., the Tinto, the Chesney, Cobar Gold, Occidental, and Queen Bee lodes appear to have been well denuded, while the Great Cobar lenses do not appear to have lost much of their upper portions by denudation. Narrow lines of siliceous gossan may be seen outcropping at times along the main lines of weakness, either in the spaces connecting the main lodes or along lines paralleling the strike of the veins. This evidence suggests that other lenses of payable ore may exist in the shattered zones containing the ore bodies known at present, but which have not reached the surface.

At first sight the lodes appear to be bedded deposits lying at the junctions of sandstone and slate belts. The absence of natural sections also by reason of the cloak of waste over the plain on which the lodes outcrop lends colour to this view. A closer inspection, however, reveals the fact that the sandstones forming the eastern wall of the long Occidental–Chesney line of lode possess a strike which only in places is coincident with that of the lodes. Moreover, the lodes dip to the east while the sandstones possess a constant and high dip to the west in the vicinity of the lodes, while easterly dips are frequent at a little distance to the east of the Chesney–Occidental line.

In the whole of the long exposure of the Occidental–Chesney–Tharsis line the sandstones never cross to the west side of the lode, that portion of the country being formed of a contorted red slate possessing a perfect cleavage developed in planes somewhat parallel to those of the lodes. At the Great Cobar red slates occur on both sides of the ore bodies, but the western slates possess characters and dips differing from those of the eastern examples. The Peak ore bodies also occur near the junction of slates and sandstones. The Queen Bee is a similar occurrence where sandstones abut against slates. To the south of the Bee lode lies another mass of altered sandstones bounded to the east by softer slates now covered by a dense cloak of waste. Zones of crushing also occur along this sandstone and slate contact. Great planes of movement are suggested for all these occurrences, along which the sandstone has been brought up against the western slates, and the low-lying country immediately to the west. All such contacts are well worth prospecting.

In almost every instance, the lodes occur on the western aspects of the residuals dotting the plain, because the dense sandstones were brought up against the softer slates to the west, and along the zone of crushing thus formed silicification occurred and lenses of ferruginous ore were deposited. As the country was slowly lowered by the combined action of weathering and streams, the denser silicified and ferruginous sandstones stood in relief while the softer slates were more easily removed. The lodes were developed in the weaker slates lying to the west of the sandstones, and they thus outcrop as siliceous masses along the western aspects of the residuals. Sometimes the lode material is highly siliceous and forms the highest portion of a residual, nevertheless it lies on the western half of the elevation. Even the Great Cobar lode itself outcrops on the western aspect of a gentle slate rise. In this case the slate of the eastern wall is harder and more siliceous than that of the west.

The most important vein system is that which passes through the properties of the Great Cobar, and the Great Cobar North. Three subparallel lines of lode here occur in proximity to each other. One only of these, namely, that to the west, has proved productive up to the present. The others have not been prospected except near the surface. The main outcrop consisted of three small lenses of gossan, the central one showing blue and green carbonate stains, the others being barren outcrops. Rich carbonates and oxides were found below the surface, and the lenses were ascertained to be connected with each other by siliceous but unproductive belts of ore. Mining operations revealed the fact that these small outcrops were only the upper portions of larger and more important lenses of ore than had been suspected at the surface.

The rich oxidised zone passed, near the ground-water level, into large masses of chalcocite and chalcopyrite, associated also with red oxide. At a depth of 400 feet the richest chalcopyrite values had disappeared and a much leaner class of chalcopyrite gradually took their places. The western portion of the lode consists generally of massive basic ore [pyrrhotite and magnetite with chalcopyrite] while the eastern portion of the ore body, as a rule, is more siliceous. A considerable mass of galena and zinc-blende occurs along the western wall, but this is clearly a later formation than the main ore body, it having been deposited along a zone of weakness formed by a slip of the ore body along the footwall (western wall) of the lode.

Great Cobar is an example of a partial replacement of shattered slates along parallel planes. Replacement has taken place characteristically in lenses which are arranged *en echelon*, both in plan and in section. It does not follow because the lenses at present worked form the only payable ore bodies near the surface that no other payable ore lenses will occur at lower levels. The lodes of the field appear to have been formed by heavy crushing action, and this, in turn, resulted in minor slips and strong crushing subparallel to the main planes of displacement. Therefore, at any depth, a lens of ore may be expected to occur on the downward continuation of the middle or eastern fissures, and especially may parallel or subparallel lenses be expected to the immediate east of the main lode. Of such lenses there may even be no indication at the surface. The galena body may be considered as the western wall of the main ore body of the Great Cobar.

The long Chesney line presents points of similarity and dissimilarity to the Great Cobar Lode. The outcrops of the former are of the nature of long, narrow lenses of siliceous gossan, connected by quartz and other siliceous gossans of unpayable nature. All lie within a heavy crush zone, and occur either along the main plane of movement or along planes, which form distributaries of the main fault. This line of movement has been traced for a distance exceeding 5 miles, extending from a point well south of the Occidental Mine to a point north of the Tharsis Mine.

Pyrrhotite (magnetic pyrites) is not a common associate of the Chesney–Occidental and Cobar Gold–Tharsis lines; nevertheless, it occurs along its whole length, and in such association as to strongly suggest that the age and origin of both the Great Cobar and Chesney lines are the same. Magnetite also occurs along this line. The payable lenses of ore consist, in the main, of slates impregnated with silica, pyrites, pyrrhotite, copper, gold, and a little silver. Galena and zinc-blende are present in all the lodes, but they appear to be younger than the main ore bodies. No true walls exist to the more important lodes, and "horses," or unproductive zones of altered slate, separate the payable belts.

In this group gold is the main mineral obtained. The copper content is generally too low to allow of profitable extraction for its own sake; on the other hand, it is present in quantities sufficient to form a serious hindrance to any of the ordinary metallurgical methods which are generally adopted for the recovery of gold. On the other hand, the ore of the Great Cobar is so basic as to admit of the introduction of a certain percentage of the acid ores under consideration in the smelting charges. Both the Chesney and the Cobar Gold Mines have been acquired by the Great Cobar. The Occidental Mine still labours under the difficulty of recovering its gold from the sulphide zone by cyanidation.

The Peak Mines also occur along large fault lines. The minerals mined are gold, silver, and lead. They are peculiar by reason of their irregular method of occurrence. The group is small as compared with those of the Chesney and Great Cobar.

Twelve miles to the south-east of Cobar lies the Queen Bee, a siliceous copper-ore body, which occurs at the junction of dense sandstones and softer red slates. The zone in which it occurs is one which has been heavily crushed, and the lode is divided into two locally by a "horse" of altered slate. A rich lens of chalcopyrite has been proved here to a depth of 660 feet.

The C.S.A. and the Tinto form another group, situated about 7 miles N.N.W. of Cobar, the country being of Devonian (?) sandstones and claystones, the latter, in places, having been altered to imperfect slates. Crushing and cleavage phenomena are not nearly so pronounced in this locality as along the more southern lines of lode.

The main C.S.A. outcrop consists of a large lens of gossan, and associated with it are several other and smaller lines of siliceous gossan. A rich bunch of carbonate of lead was found at and near water-level in the C.S.A. Mine. Rich copper and lead were also struck at the same level in the adjoining Tinto Mine. Immediately below these shallow enrichment zones, the ore passed into masses of lean cupriferous pyrites and pyrrhotite. Later movements along the old fault plane have allowed of the introduction of galena and zinc-blende. Prospecting operations to the east of the lode during the year 1911 resulted in the discovery of a vein of siliceous chalcopyritic ore in the C.S.A. Mine at the 450-feet level. At this depth and thence also to the 530-feet level, the Tinto shaft passed through a good basic copper ore.

Conditions of the Ground Water.—In the Cobar District permanent water is generally found at depths varying from 200 to 450 feet. In the Great Cobar Mine the depth was about 280 feet, the C.S.A. about 457 feet, the Tinto about 430 feet, the Chesney about 360 feet, the Occidental about 320 feet, the Gladstone 200 feet, the Queen Bee about 250 feet, and the Cobar Gold Mine about 320 feet. A strong circulation appears to take place along the Chesney line of weakness, the water generally entering the workings along "floors."

A study of the ore deposits points inevitably to the conclusion that the present water-level is of decided age, and also that there are no signs of a former important ground-water level, either above or below that of the present. This conclusion is based upon the known distribution of the oxidised and chalcocitic ores.

Depth of Oxidised Zones.—The secondary enrichment of ore consists of the formation of galena chalcopyrite and chalcocite (grey ore) among the sulphides, and of malachite, azurite, cuprite (red oxide), native copper, carbonate of lead, and chloride of silver among the non-sulphide ores. The carbonates of copper and lead appear to occupy the highest positions in the lode. At slightly lower levels come the red oxides and native copper, associated with grey ores. Below this zone comes grey ore associated with chalcopyrite (yellow ore), and lower than this again rich yellow ore may be found in certain mines.

At the C.S.A. and Tinto Mines a barren gossan was passed through to a depth exceeding 400 feet below the surface. Thence a mass, 30 or 40 feet in thickness, was met with, consisting of carbonate of lead and grey ore (chalcocite) with some other copper ores and chloride of silver. A mass of lean cupriferous pyrites and galena occurred below this. The upper limit of the zone of oxidation in these mines is irregular, the surface of the rich lead body varying as much as 30 feet vertically over very short horizontal distances.

Genesis of the Ore Bodies.—Several important facts must be taken into consideration in any discussion as to the origin of the ore deposits of the Cobar District. Thus:—

(1.) With the exception of two small orthoclase-porphyry "pipes," igneous rocks are absent from the large Cobar district. The conditions also surrounding their occurrence suggest no direct connection with the ore deposits.

(2.) The ore deposits were formed along planes of great dislocation.

(3.) The lodes were formed in the core of a great mountain range, the present veins being visible to-day only as the result of the denudation of the great mass of sediments in which they had been deposited. In other words, the ore deposits had been formed under conditions of great heat and pressure.

(4.) The primary ore of the earlier formed deposits consists of pyrrhotite, magnetite, Ekmannite (?), chalcopyrite, gold, and silver.

(5.) Geologists and physicists agree that magnetite and pyrrhotite can only be formed under conditions of great heat.

(6.) Movement has taken place in somewhat later times along the old planes of weakness, and a fresh set of primary minerals have thus been introduced. These include quartz, iron pyrites, chalcopyrite, silver, gold, galena, and zinc-blende. Pyrrhotite, magnetite, and Ekmannite [silicate of iron] are characteristically absent from this younger set of minerals.

(7.) The lodes, when consisting essentially of pyrrhotite, magnetite, and chalcopyrite, have but few traces of true walls, and appear to weld the eastern and western country together, while the lodes characterised by the absence of the magnetic pyrites and iron oxide possess definite walls, and frequently show the presence of a "dig" along one wall.

The idea suggested by this evidence is that the earth's crust in the locality under consideration was dislocated to a great depth, and that by the great relief of pressure thus afforded in the deeply seated rock areas there was a tendency among the heated rocks, to rise along the planes of dislocation, and mineralised vapors and waters therefrom rose, and were deposited in the zones of crushing by processes of replacement. In the more coarsely-textured rocks silicification was pronounced, while in the more finely-textured rocks basic replacements were characteristic. Thus, in the Cobar Gold Lode the silica percentage is about 80, that of the copper about 1·3, and of the iron 8. In the Great Cobar Lode the silica percentage is about 17, that of the sulphur about 15, of the iron about 41, of the copper 2·6, and of the alumina about 7.

In the latter lode the minerals represented in the main are massive pyrrhotite, magnetite, Ekmannite, chert, chalcopyrite, quartz, and silicified slate. No igneous rocks are associated with these minerals; nevertheless the magnetite, Ekmannite, and pyrrhotite are believed to be dependent upon conditions of considerable heat for their formation. The mineral association thus points to the formation of the Great Cobar Lode at a considerable depth below the earth's surface. The structure of the field also tends to confirm this idea of deep-seated origin for the lodes.

It is a well known metallurgical principle that copper has a greater affinity for sulphur than iron has under ordinary pressures, and it also appears to be true that this holds good for conditions of considerable heat and pressure. With a total of 15 per cent. of sulphur, with 2·6 per cent. of copper, and 41 per cent. of iron, it is therefore certain that the copper would be easily satisfied by the sulphur, and that the balance would combine with the iron, inasmuch as the iron has a greater affinity for sulphur than for oxygen and silica under conditions of considerable heat and pressure. But after the available sulphur had been used up by the iron, there still would remain a considerable percentage of iron. This, under the peculiar conditions of heat and pressure existent, and in the absence of ordinary wandering superficial waters, would tend to form silicates and magnetic oxides. It is probable that the pyrrhotite ore was formed to economise the sulphur, the pyrrhotitic form being possible of formation at temperatures exceeding 500° Centigrade. It is certain, in any case, that where the sulphur content of lodes is large in the Cobar district there iron pyrites is formed, as a rule, instead of pyrrhotite, and that neither magnetite nor Ekmannite are formed in such cases.

At a later period the lodes appear to have slipped upon themselves and to have crushed the weaker bands of slate country. Another hydrous segregation found an escape along this fresh zone of crushing, and masses of galena, zinc-blende, iron pyrites, and chalcopyrite were deposited in this manner alongside of the older pyrrhotite, magnetite, and Ekmannite masses. A study of the deposits suggests that the galena, zinc, and iron pyrites were not deposited under the peculiar conditions of heat and pressure which had accompanied the earlier precipitations. In these later veins also the ore minerals do not generally die out gradually into the country, but have fairly well-defined walls.

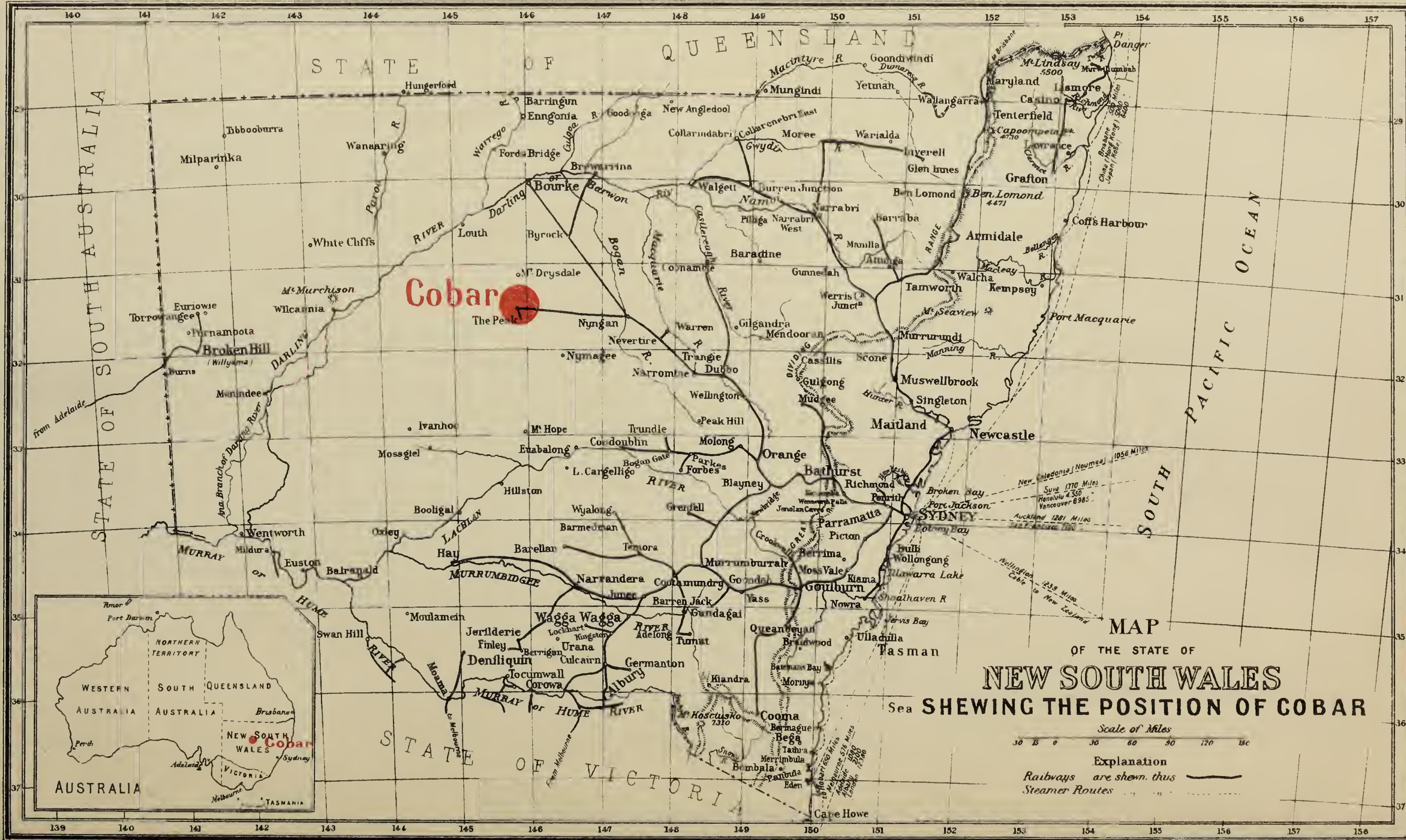
Influence of Topography.—The ore lenses now being worked were not exposed until the mountain range enclosing them had been gradually worn away by denuding agencies. Since their exposure, however, the country has been subjected only to minor fluctuations of level, accompanied by erosion, which moved along slow lines. The Cobar Plain has suffered little alteration for a long period of time. Possibly not more than 200 feet of material have been removed from its surface during the later geological divisions of time, and such amount of loss has but slightly influenced the oxidation of the ore bodies, especially as no dislocations have affected the region since Palæozoic time. The effect of such oxidation has been to form chalcocite bunches near water level. With and beneath these in turn rich masses of yellow ore have been formed by similar processes. With and above the yellow and grey ore (chalcocite), the usual association of malachite, azurite, tenorite (?), cuprite, and native copper is found. Below these products of oxidation come the primary pyrrhotite (magnetic pyrites), magnetite, chalcopyrite (yellow ore), and quartz, associated with altered slate.

Such oxidised masses here described appear to have been derived from the leaner primary magnetic pyrites and yellow ore by the action of descending sulphate solutions. In the case of the grey and yellow ore enrichments, the sulphates (oxidised agents) merely enriched the sulphides without changing them to oxide ores.

In the lead and silver mines, solutions have produced masses of carbonate of lead (with chloride of silver) at and near water-level.

No trace of two distinct zones of secondary enrichment, arranged vertically under one onother, has been found in the Cobar mines ; hence, the topography, from this fact also, appears to have been stable for a long period.

Influence of Country on Ore Deposition.—The lenses or shoots of payable ore appear to be referable mainly to physical causes. The main replacements of country by the iron, copper, silver, gold, and silica minerals occur among the softer slates. Thus the Queen Bee copper deposit lies in slates at their junction with heavy sandstones. The Occidental lies at the junction of slates and sandstones, and the Chesney also lies in a zone of soft slates. The Cobar Gold pay shoot occurs in a mass of crushed red slate, the shoot being cut off to the north by sandstones, and to the south by hard sandy slates. The Great Cobar lenses occur in relatively soft red slates, and not in the associated harder and coarser varieties, while the C.S.A. and Tinto lenses occur in claystones. Where the lodes are wide and basic, there the country is a reddish slate at the surface ; where the lodes "pinch" and the iron content gives place to quartz or impure silica, there the country is of coarser and denser nature.



MAP
OF THE STATE OF
NEW SOUTH WALES
SHEWING THE POSITION OF COBAR
Scale of Miles
Explanation
Railways are shewn thus
Steamer Routes
STATE OF QUEENSLAND
STATE OF SOUTH AUSTRALIA
STATE OF VICTORIA
SOUTH PACIFIC OCEAN
Tasman Sea
Cobar
The Peak
Bourke
Broken Hill
Wilcannia
Nyngan
Dubbo
Orange
Bathurst
Sydney
Newcastle
Maitland
Goulburn
Wagga Wagga
Albury
Hay
Deniliquin
Armidale
Tamworth
Grafton
Port Jackson
Botany Bay
AUSTRALIA
Lithographed & Printed at the Department of Lands Sydney, New South Wales 1912

Chapter I.

HISTORY AND GENERAL REMARKS.

Communication.

Cobar, the most important copper district in New South Wales, is situated in the western portion of the State, and is distant 464 miles from Sydney by rail.

From Sydney and from the eastern portion of the State of New South Wales generally, the town of Cobar is approached by a railway of standard gauge (4 ft. 8½ in.), passing through Bathurst, Orange, Dubbo, and Nyngan. From Adelaide, the Darling River is navigable to Wilcannia, Louth, and Bourke, thence coach may be taken for distances respectively of 160, 80, and 100 miles to Cobar.

The only recognised approach, however, is by rail from Sydney, the journey occupying nineteen hours (464 miles).

Climate and Vegetation.

The climate of New South Wales becomes more arid with progress westward. Cobar itself comes within the sub-arid zone. The greatest rainfall recorded for any one year during the period in which observations have been taken was 31·48 inches, and the minimum rainfall was 5·29 inches, the average being about 15 inches for a thirty years' record. The maximum and minimum temperatures recorded were 118·7 (year 1889) and 25·0 (year 1882), respectively. The low elevation of the plain (800 feet) of erosion comprising the district is in great measure responsible for the heat of summer, but the still less elevated portions of the district proper is at Bourke (350 feet above sea-level). Bourke, Louth, and Wilcannia (300 feet) have reached extreme shade temperatures of 126° Fahrenheit. The climate of Cobar in the winter, however, is magnificent and bracing.

Desolating winds are a frequent and trying feature of the climate. These are consequences of the situation of Cobar in the interior. In the summer dust-storms are common, and at times these become even terrifying. An experience of the Writer at the Cobar Peak, on the morning of the 11th November, 1910, may here be given, so as to furnish an idea of the storms which at various times traverse these regions. The storm under consideration was not classed as one of the most violent known at Cobar. At the Peak, however, where the Writer experienced it, the storm was much more severe than at the main township of Cobar. Towards noon the clouds grew very black, and the thunder became pronounced. A huge wall of red dust could be seen approaching from the west, and one particularly large mass preceded the main cloud in its passage across the Amphitheatre Station. This advance guard approached as a huge wheel-like mass, about 2,000 feet in height, with an impressive rotatory movement. Over the Occidental a northern outlier of the dust-storm towered as a monstrous red pillar. Still farther northward the storm appeared to lose its intensity. At the first onset of the storm the trees were bent almost to the ground, the air became dark as night by reason of the enveloping dust, and a strange sweeping sound accompanied the passage of the dust over the ground. At intervals the gale would form rifts like chimneys through the red cloud, and one was then enabled to see about 20 yards ahead. This lasted only twenty minutes, the dust disappearing under a heavy fall of rain (65 points).

Sometimes these dust storms last for many hours.

The monsoonal rains are expected in midsummer, and the failure of these at certain periods constitutes the condition known as "drought" in the interior of Australia.

Vegetation.—The low average rainfall is evidenced by the relative absence of grasses. The country, however, is covered with beautiful shrubs and trees. A common height attained by *Eucalyptus intertexta* is 60 feet, while specimens have been seen as much as 80 feet in height. The wilgas, mulgas, currawongs, eremophilas, pines, ironwoods, quandongs, leopard woods, beefwoods, pittosporums, needlewoods, and bimble-boxes are specially beautiful by reason of their symmetry and their pendulous and umbrageous habits. When the keen winter winds have gone and the spring returns, the country becomes a veritable blaze of colour by reason of the flowering shrubs. The currawong, the cassias, the wild orange, wild lemon, fuchsia, turpentine, sage-bush, budtha, verbena, wattles, and needle-bushes are the most attractive of these, and their scent fills the air for a considerable distance around.

Unlike the plants east of the Main Divide, the central western plants are reputed to possess distinct fodder values. Chief among these are the booligal, the kurrajong, the currawong, the leopard woods, the mulgas, the myall (boree), and the rosebush. Of these, however, the myall and the booligal do not grow in the neighbourhood of Cobar. Cattle thrive on mulga and other plants, such as rosebush.

The plants of Cobar exercise a selective action, both as regards their foods and their situation with respect to the weather. Thus the dense crushed sandstones of the Cobar Series are occupied by growths of the Sifting Bush (*Cassinia*), Whipstick Mallee (*Eucalyptus viridis*), *Eucalyptus Morrisii*, the Verbena (*Prostanthera striatiflora, Prostanthera Leichardtii*), heath (*Eriostemon difformis*), and the White Pine (*Callitris robusta*), and the gorgeous *Petalostyles Labichioides*. The quartzite outcrops of the Amphitheatre Series (Devonian) support abundant growths of *Beyeria viscosa, E. Morrisii, Cassinia,* Wild Fuschia (*Eremophila Latrobei*), and *Acacia salicina*. The broad and shallow alluvial flats are covered with growths of Bimble box (*Eucalyptus populifolia*), Budtha (*Eremophila Mitchelli*), Yarran (*Acacia homalophylla*), and *Santalum acuminatum*. The Currawong (*Acacia doratoxylon*) loves hilly ground of any description; the Silver Wattle (*Acacia decora*) follows the gravelly hills of the Cobar Series; the Turpentine (*Eremophila Sturtii*) is found on the gentle slopes of the Devonian and the Silurian. Sandy Devonian slopes are occupied by Leopard Woods (*Flindersia maculosa*), but the Silurian slates are carefully avoided by them; while the Emu Apple (*Pittosporum phillyrœoides*) flourishes equally well on gentle rises of both Devonian and Silurian rocks. The Cassias, the Wild Lemon (*Canthium oleifolium*), the Wild Orange (*Capparis Mitchelli*), the Mulga (*Acacia aneura*), the Rose-bush (*Heterodendron oleifolium*), the Emu-bush (*Eremophila longifolia*), the Warrior-bush (*Apophyllum anomalum*), the Red Box (*Eucalyptus intertexta*), the Beef-wood (*Grevillea striata*), the Needle-wood (*Hakea leucoptera*), the Iron-wood (*Acacia excelsa*), the Needle-bush (*Acacia cyperophylla*), the Belah (*Casuarina Cambagei*), and others, frequent gentle rises, some preferring slate country and other sandy formations. The red and white Mallees (*E. oleosa and E. dumosa*) form thick clumps in gravelly country. For

Photo. C. E. Murton.

Fig. 1. Green Mulga (*Acacia aneura*).
C.S.A. Mines, Cobar.

Photo. C. E. Murton.

Fig. 2. Cobar Coolabah (*Eucalyptus intertexta*).
Near C.S.A. Mines, Cobar.

PLATE III.

Photo. C. E. Murton

Fig. 1. Red Box or Gum (*Eucalyptus intertexta*), Cobar.

Photo. C. E. Murton.

Fig. 2. Wilga (*Geijera parviflora*), Cobar.

fuller descriptions of the plants, see papers by Mr. R. H. Cambage, L.S., in Linnean Society's Proceedings of New South Wales for years 1900–1 ; also a paper by Archdeacon F. E. Haviland in Proceedings of Linnean Society, New South Wales, 1911, pp. 507, 540.

The desert timber is excellent for fuel purposes, especially the red and bimble boxes, the myall, yarran, and iron-wood. All of these timbers are excessively hard.

Water Supply of Cobar.

This section is based mainly upon notes supplied by Mr. S. M. Cummins, District Works Engineer of Cobar.

In the sub-arid district under consideration, devoid of good natural dam sites by reason of the flatness of the country, it is highly important to understand clearly the best means of conserving water. In great measure the area consists of large yarran flats, which are "absorbent as a sponge." . . . . "Not only do these yarran-covered flats fail to yield 1 per cent. of the rain-water which falls upon them, but they also absorb a large amount of the water shed on to them from outside sources."

Present Water Supply.—The site of the Cobar town reservoir is a little to the west of the 4-mile peg on the Louth Road. The dam is anchored to a belt of rocks called the Alley Beds, which here dip under a yarran flat for a distance of about 400 yards. The greatest height of the embankment is about 25 feet, and of the by-wash 16 feet, above the surface level. The zero gauge is at the surface level, and the excavation below this is only 4 feet in depth. The reason for making such a shallow excavation is that the supply is thereby kept more pure, the great amount of evaporation in the district (8 feet per annum) being compensated for in great measure by the discharge into the reservoir of water from the underlying gravels or sands of the yarran flats.

The catchment area is about 12 square miles. The drains in the early days were made too small, and the discharging waters simply overflowed such drains, and were absorbed by the flats. "It is absolutely necessary," says Mr. Cummins, "to keep the feeding water into wide shallow trenches on the edges of the great bimble box and yarran flats, where the ground is hard and non-absorbent, to secure good results."

Proposed Scheme by Mr. S. M. Cummins.—Site for dam on Yanda Creek, about 15 miles above railway crossing, 10 miles east of Cobar. Catchment 100 square miles approximately. An embankment here, about 440 yards long and 20 feet high, would conserve 12 feet of water above the natural surface. By carrying an embankment 5 feet high for a distance of from 1 to 1½ miles, the depth of the water conserved could be increased by 6 feet. An extensive system of wide flat drains would be necessary, because of the large yarran and box flats existing on the catchment area.

Proposed Gundabooka or Darling River Water Scheme.—A survey of this proposed route for fetching water to Cobar has been carried out by the Works Department. An approximate estimate of the cost is £250,000.

Three pumping stations are proposed—one at Gundabooka, on the Darling River, at a height of about 325 feet above sea-level, another near Gundabooka Mines, and a third at Drysdale. The main reservoir is proposed for Fort Bourke Hill, at a height of about 1,000 feet above sea-level. The water is to be elevated by turbine pumps. The class of pipe proposed is unknown, but in all probability its diameter would not be less than 1 foot.

Literature.

The subjoined list embraces only the more important publications and references dealing with mining at Cobar :—

Carne, J. E.—

(*a*) The Copper-mining Industry of New South Wales. Mineral Resources, Geological Survey, N. S. Wales, No. 6. Second edition, 1908. (First edition, 1899.)

(*b*) Annual Report, Department Mines, N. S. Wales, 1905; pp. 139–142, inclusive.

Janin, Louis, jun.—Mineral Industry. Vol. viii, 1899; pp. 203–214.

Pittman, E. F., Mineral Resources of New South Wales, 1911, pp. 156–169.

Weed, Walter Harvey.—The Copper Mines of the World, pp. 158–159.

Young, Lamont.—Annual Report, Department of Mines, 1880, p. 262.

Mr. J. E. Carne points out that the Cobar lodes occur on independent and parallel courses, and both on physical and mineralogical evidence he disproves the idea that the apparent offsetting of the main lodes may be explained as the faulting of a once continuous lode. He favours a Silurian Age for the strata containing the Cobar lodes. He considers, moreover, that the introduction of iron and silica into the country by the formation of the ore bodies has caused the lodes to outcrop on the residuals dotting the Cobar Plain. Attention has also been directed in his various reports to the difficulties which the companies working the different gold veins would encounter with depth from the presence of copper and other sulphides; and he insists upon the necessity for co-operation among companies possessing low-grade basic and acid ores respectively.

Janin calls attention to the association of the lode outcrops with the "so-called mountains," and to the influence of the opening of the railway to Cobar and the introduction of low freights on the copper industry at Cobar.

Mr. Pittman bases his notes mainly upon those of Carne and Janin, and calls attention to the copper averages and the dividends of the Great Cobar up till 1889, pp. 168 and 169.

Weed appears also to have based his note upon the reports of Carne and Janin. "The deposits," he says, "are all regarded as bedded veins in Silurian schists . . . Copper glance, chalcopyrite, and magnetite occur in the primary ore, while the oxidised ore contains the usual variety of minerals. The ore is notable for the amount of bismuth it carries, which caused considerable trouble in the earlier history of the mine, before electrolytic refining was practised." (p. 59.)

It may be mentioned here that bismuth causes little or no trouble at present in the refining of Cobar copper. Again, the sinking of deep workings in the Cobar lodes has shown that copper glance is a secondary ore, and that the average value of the cupriferous pyrrhotite is about 2·6 copper. (See returns in this report, page 108.)

Much valuable information concerning the Cobar mines may be found in the reports of the various wardens, mining inspectors, and mining registrars in the Annual Reports of the Department of Mines between the years 1875 and 1911. Among these, the reports of Inspectors D. Milne, J. R. Godfrey, R. Schloesser, and J. Polkinghorne may be mentioned. The reports of Mr.

Inspector J. Polkinghorne during the years 1904–1912 are especially instructive, while both Inspectors Godfrey and Schloesser draw attention to the necessity of treating the low-grade gold deposits of the Chesney-Occidental line of lode on a very large scale.* Valuable notes on the Peak and other lodes are contained in the reports of Mr. Inspector Milne.

Numerous references to the field are also to be found in the *Australian Mining Stardard.* The notes on the C.S.A., Tinto, and Occidental Mines, by Mr. F. Danvers Power, M.I.M.M., are contained therein. [Volume for 1907, p. 389.]

References to mining at Cobar are supplied in Mr. W. S. Dun's "Papers on Economic Geology." Records, Geol. Survey, N.S. Wales, 1900, vi, Pt. 4. Numerous references to Cobar mines are also to be found in a register of mining localities in New South Wales by Mr. O. Trickett, L.S.

HISTORY.

The historical notes here presented have been selected from information supplied by Messrs. H. J. Cornish, Neil Morrison, and Frank Lean. The "Copper Mining Industry," by Mr. J. E. Carne, has also been drawn upon freely in the preparation of this chapter.

It is difficult for people unaccustomed to any but hilly and well-watered countries to appreciate the trials which beset the prospector in his search for mineral lodes in the interior of Australia. Cobar lies in an immense rocky plain, devoid of streams, except after a period of heavy rain, and with here and there only a small natural waterhole. These infrequent and small waterholes in turn are not permanent, except in rare instances; and in the whole of the great Cobar district the blacks alone knew of these scattered water supplies. At Cobar itself, in the outcrop of the great lode, one of these waterholes occurred, and as this formed a sort of central or meeting ground between the Mossgiel and Gundabooka blacks, and moreover as a "raddle" or earthy iron oxide occurred at the same spot, the two tribes just mentioned were accustomed to meet here periodically in connection with their religious ceremonies and warlike tendencies.

Previous to the great flood, about the year 1870, when the Darling River overflowed its banks and spread out in places as much as 50 miles across, the interior of New South Wales had been visited by a succession of severe droughts. Owing to the aspect of affairs during this severe dry spell, contracts for sinking wells and the construction of overshot dams were let by the scattered pastoralist community. Among others, three men, named Campbell, Hartmann, and Gibb had taken contracts for the sinking of wells and the construction of dams. Having followed the occupation of mining at Bendigo, they were ever on the alert for signs of gold-veins while engaged both in sinking wells and in travelling across country. They sank wells at the Priory Station, to the south of Cobar; and then, as this station became deserted owing to the protracted drought, they made their way to the Bogan, towards Bourke, constructing dams en route. Then came the great flood, and the country round Cobar once again had an abundance of water. Campbell, Hartmann, and Gibb now determined to return to the Priory, in accordance with an agreement made with a family named Kruge, the latter having moved south from the Priory towards the Lachlan with sheep at the same time that the others had departed north for Bourke. On account of

* Ann. Rept., 1900, p. 102.

the flooded nature of the country around Bourke, the three tank-sinkers engaged the services of two aboriginals named Frank and Boney to guide them to the Priory. Boney was the pilot. From Bourke he brought them by boat to Louth, down the Darling River, the stream at that time presenting the appearance of a huge lake. Thence by Wittagoona they came to Cobar. At this place the camp was made by Boney alongside the natural rock hole situated on the top of the gentle rise, and near the site of the present smelting office of the Great Cobar Company. The size of the cavity was about 8 feet by 5 feet on the surface, and the maximum depth of the water was about 5 feet. The sides of the cavity consisted of kaolin and "raddle," with streaks of green and blue carbonates of copper "showing in the eastern wall," says Mr. H. J. Cornish, "like the rivers on a map." The three Bendigo miners were accustomed only to the outcrops of gold-veins, nevertheless they were impressed by the appearance of the minerals, and took some with them as they continued their way south. At Gilgunnia they met the Kruge family, who were returning northwards towards the Priory after the flood. To them the tank-sinkers showed the carbonate specimens, and Mrs. Kruge, who had been a "bal gal" in Cornwall, assured them of the valuable copper deposit indicated by the specimens they carried.

Campbell, Hartmann, and Gibb then returned at once to Bourke, with the intention of securing the ground. They showed their specimens to Mr. Joseph Becker, a merchant of Bourke, and he, together with Mr. Bradley (of Cobb and Company), Mr. Russell Barton, and "Gundabooka Smith," took up 40 acres over the outcrop, and thus formed the first Cobar Company. Three weeks later the North and South Cobar blocks were taken up.

About March, 1871, the first Government Surveyor arrived on the field. To locate the "outlandish spot," says Mr. Cornish, "he had recourse to observations of the stars." Cornish placed the first survey pegs. At the same time a large and curious ironstone outcrop (Plate 5), near the present rifle-butts, was pointed out by Boney, the Louth aboriginal. This rock, according to aboriginal tradition, was the Devil's Tent, under which the Evil One lay and from this distance watched the religious ceremonies of the blacks at the native well.

No work was done for some time after the survey by Mr. Evans. Afterwards, it was decided to send a dray-load of ore to Adelaide. Eight bullocks took the load of 3 tons to Louth, thence it went to Adelaide by boat. It was there regarded so favourably that men came over from South Australia to Cobar to work the mine systematically.

John Varcoe was the first manager. Then Captain Lean (Plate 4) took management, towards the close of 1871, bringing with him six miners from Moonta.

Water was at first obtained from the depression in the actual copper outcrop, and this reservoir was protected by logs, to keep off dingoes and other animals. Afterwards, a tank was formed near the junction of Linsley and Becker streets, and out of this every human being and animal drank, and withal the health of the people did not appear to suffer in the least. At a slightly later date, water was carted to a small tank between Wittagoona and Cobar to supply travelling teams.

At this time communication was only with difficulty maintained with the civilised world. The people had the choice of going to Adelaide by way either of Bourke or Louth, or to Sydney by way of Bourke. The distance at present to Sydney *via* Nyngan is 464 miles; the distance to Sydney in 1870 *via* Bourke was 635 miles. Water, however, was almost an unknown quantity across country to Nyngan, and the dense growths of hop-bush, pin-bush,

Photo. lent by T. F. Lean.

Captain Lean.

One of the First Managers of Great Cobar Mine.

needle-bush and other plants made travelling difficult in that direction. On the other hand, although the way to Sydney by way of Bourke was 170 miles longer, yet the way was cleared to Bourke, and a natural "claypan," named the Yellow Waterholes, could be relied upon for water supplies. During the summer time, a start was made for Bourke at sundown. On the road to Louth, water could be obtained at Wittagoona and at Kerriguuda by making short offsets from the direct road. Teams travelling to Louth with ore could only go at such times as water was fairly plentiful.

The first shaft of the Great Cobar was sunk immediately east and north of the old rock hole. Good copper was found from the surface. The present North Cobar was prospected about the same time that the South Cobar was taken up. Captain Goldsworthy took charge of the South Cobar, and Captain Polglaise became manager of the North Cobar.

Occidental.—The success of the Great Cobar led to the immediate search for similar lodes in the district. The miners, however, searched for solid gossans and bestowed but slight attention on the siliceous "blows" occurring on the low residuals which dotted the plain, for they were Cornishmen whose motto was :—

"There's never a mine so rich and fat,
As that which wears the iron hat."

In the year 1871, the Occidental was taken up for copper by H. J. Cornish and others. It was surveyed by Mr. J. C. Dalglish, who designed the leases for the famous Broken Hill Lode some years later. The opportunity was taken to explcit the Occidental while waiting for the Darling River to rise so as to convey the Cobar ore to Adelaide. A shaft was sunk where the present main shaft of the Occidental occurs. After 100 feet of sinking and 50 feet of cross-cutting thence to the east, the mine was abandoned and lay idle for years. A trial crushing of 2 tons, in the meanwhile, had been made at Ballarat. The stone yielded 1 ounce of gold to the ton.

C.S.A.—Still on the look-out for dense gossans, the miners located a large boat-shaped lens of brick-red gossan about 7 miles to the north-north-west of Cobar. The date of this discovery was about three or four months later than the finding of the Occidental (United). An old prospector named Tom O'Brien found the lode, and after some search he picked up a small piece of copper carbonate in the gossan at the spot where the "underlay shaft" was sunk at a later date. Cornish, Gibb, and Conlay were induced to visit the spot, and found a very small vein of ore less than 12 inches in width. They departed for Bourke very quietly in the hope of securing the ground without opposition. It is said by some that they even muffled the hoofs of their horses with bags so that their movements might not be heard in the clear night air of the desert. The party had not the ready money for payment of the required lease, but this, a sum of £20 (40 acres at 10s. an acre), was supplied by one Nancarrow, of Maitland. The mine thus started was called the C.S.A., because it had been started by a Cornishman, a Scottishman, and an Australian.

Amalgamation.—In January, 1876, the Cobar and Southern Cobar Copper-mining Companies (Limited), became amalgamated. The name of the new company was the Great Cobar Copper-mining Company (Limited). The number of shares was 80,000, at £1 each.

Prior to this amalgamation the Southern Company had sunk Renwick's shaft to a depth of, approximately, 300 feet, and they had shipped 278 tons of ore, averaging 37 per cent. copper, to Adelaide. The value of the copper contents was £5,166.

"During the first half of 1875, two smelting furnaces were completed and a third begun; 316 tons of ore were smelted, yielding about 45 tons of coarse copper; ore at grass valued at £3,945."*

From the Great Cobar prior to 1876, about 3,000 tons of copper ore, of an average value of at least 30 per cent. copper, had been shipped to Adelaide.

The Great Cobar North adjoins the Great Cobar, but has never been absorbed by the latter. The outcrop of the Great Cobar is continued northward into the Great Cobar North, but the solid gossans have here given place to thin siliceous gossans, which have been prospected by four shafts, without any material success up to the present. A little lean ore was struck in No. 3 shaft at the higher levels, but in the early part of the present year (1911) magnetite, pyrrhotite, chalcopyrite, and other minerals indistinguishable from those which characterise the lode of the Great Cobar, were found in the North Cobar at a depth of 1,450 feet.

About the year 1874 Captain Thomas came from Peak Downs to commence a smelting campaign; 25,000 bricks were made at Mopone, 7 miles north of Cobar. Firebricks had been brought from Swansea, *via* Louth, the cost for each brick being estimated at 2s. 6d. Thomas put up six reverberatory furnaces, and Dunstan, who succeeded him in 1878 (?), erected another six.

In 1872 the United was taken up a second time, and abandoned. At a still later date it was reopened by Cornish, Penhall, and Lean, and then re-christened the Occidental, because, at that time (1889), it was the most western gold supposed to exist in New South Wales. In prospecting this ground in 1871 the prospectors had secured twelve blocks of 40 acres each. These were arranged along the line of strike of the lodes, and included the present Great Western, the Wood Duck, the Young Australian, the Mount Pleasant, the Burrabungie, and the Chesney lodes. The hill upon which the Chesney is located was known in the early days as Mount Tabor. Both this and the almost inappreciable rise known as Mount Pleasant were named after hills mentioned in Scripture.

With the introduction of smelting, the Cobar mines gradually became more important. It was no longer necessary to mine ore averaging from 20 to 25 per cent. copper. The large heaps of seconds, also, were treated, and run into blister copper.

Gold in Cobar Copper Ores.—"Though gold was early known to be present in the Cobar Mine, and in the free state was occasionally noticed in the oxidised ores, no attempt was made to turn it to account until the Cobar syndicate began operations in 1893–4.

"In 1882 Mr. Russel Barton secured a specimen of malachite showing coarse gold, and the Company's caretaker (the late Mr. Gillard) had in his collection a specimen of slate from the outcrop containing a rich seam of scaly gold."

"In 1881 an assay was made in the Departmental Laboratory of a sample of the Cobar copper obtained by boring through several ingots, with the following results:—

Gold	2 oz. 12 dwt. 4 gr. per ton
Silver	1 oz. 5 dwt. 0 gr. ,,
Copper	92·65 per cent.

. . . . . Cobar copper, for years, must have proved a lucrative investment for metal-buyers in England, who secured it a lower market rate than Chilian bars, notwithstanding its valuable gold contents. . . . . Mr. Barton states that the gold contents of the copper produced during early operations varied from half an ounce to 3 oz. per ton. Not till the

* J. E. Carne, "Copper-mining Industry," 1908, p. 246.

Photo. T. F. Lean.

Devil's Rock, $2\frac{1}{2}$ miles North-west of Cobar.

Siliceous Ironstone Outcrop.

latter half of 1894 did the Company draw the attention of buyers to the presence of gold and silver in their copper in recoverable quantities. The immediate result was an advance of about £7 per ton over the current quotations for Chili bars."

"The sulphides from the working stopes, in 1898, were reported to yield from 2¼ to 3 dwt. of gold per ton. Concentration at the present day is extreme compared with past operations. . . . . . The market value of the Cobar copper is now enhanced some £20 odd per ton by the contained gold and silver. . . . ."*

In 1889, operations at the Great Cobar Mine "had to be suspended owing to the extremely low price of copper and excessive cost of transport." The failure of the Société des Métaux, and the collapse of the "copper boom" it had originated, were the direct causes of the Company's suspension, as an agreement had been entered into for a term of three years with the Société for the purchase of the entire output from the Cobar Mine at £60 per ton on board ship at Sydney. In 1893, however, the mine was let on tribute to the Great Cobar Mining Syndicate, which began operations when the average value of copper was but £39 per ton, and successfully introduced the cheaper and more rapid blast-furnace method of reduction which revolutionised the copper industry at Cobar. A previous attempt with blast-furnaces (not water-jacket) was made in 1885, when three were erected at a cost of £5,000. After a short campaign with charcoal fuel, they were discarded, though the mine manager, Mr. J. Dunstan, regarded some of the experiments as satisfactory. Three hundred and twenty-five tons of ore were smelted in these furnaces. The cost of charcoal alone would have rendered profitable working impossible at this date. Rapid and certain railway transit has effected no less complete a revolution in cost of production. Prior to the advent of the railway to Cobar in 1891, the Company was dependent on teamsters for freightage to and from the mine, and the latter again were entirely dependent upon the seasons. During a drought in 1882–3, it was found impossible to maintain the necessary supply of firewood, whilst the stock of copper in the sheds at the mine increased to over 1,200 tons, owing to the impossibility of transport by team over 300 miles of drought-stricken country to the nearest railway.

"The water supply at this period became so restricted that armed patrols guarded the only available tank and doled out a scanty allowance to the residents. Travellers were allowed but one drink for themselves and horses.

"Significant of the changed conditions is the fact of continuous operations during subsequent disastrous and protracted droughts.

. . . .

"During the operations of the Company from 1876 to 1893, 213,182 tons of ore were raised, and 23,610¾ tons of copper produced."†

The Peak Gold-mines were discovered about 1887, of these the main were the Blue Lode and the Peak Prospecting Company.

Cobar Gold-mine.—In the same year the large and important Cobar Gold Lode was discovered. The occurrence is only a short mile from the Great Cobar Mine, and the outcrop is one of the boldest in the locality. It is strange that a body of siliceous ore 700 feet in length and averaging 40 feet in width, and containing an average value of gold exceeding 8 dwt. per ton of ore, should have been left untried for so many years after the commencement of mining operations at Cobar. Payable stone was taken from this

* Carne, "The Copper-mining Industry," pp. 236, 237.
† Carne, "The Copper-mining Industry," 1908, p. 230.

lode to the 225-feet level, when sulphides were encountered, and free milling became less and less productive. Every lode along the long Chesney line has had to face the same difficulty, namely, the increasing cost of gold extraction as the sulphide zone was entered upon. The copper content is too small to allow these mines to be worked as copper-mines. Nevertheless, it is sufficient to cause trouble in the ordinary gold-extraction processes. It has become increasingly evident that these acid ores, with their moderate gold and copper contents, need smelting in conjunction with some ore containing abundant iron. Already the Great Cobar has absorbed both the Chesney Mine and the Cobar Gold-mine, and it is possible that in the near future the basic ore of the C.S.A. and Tinto Mines may be utilised in conjunction with acid ores such as those of the Gladstone (See Appendix IV.)

The main points in the history of the field since 1907 may now be rapidly enumerated.

1898.—Five blast furnaces in use at Great Cobar. Want of main shaft emphasised.

Fort Bourke (Cobar Gold), 100-stamp mill. Cyanide plant erected.

Occidental erected cyanide plant to treat large stacks of tailings.

1899.—New shaft and Barton's shaft of Great Cobar, 650 feet deep and connected at 540 feet level. Hot-blast furnace completed. Chesney underwent extensive development.

1900.—Great Cobar Mine purchased in 1900 for £500,000 by the Cobar syndicate, which had been working it for seven years on tribute. Great Western main shaft 406 feet deep. New main shaft being sunk at Occidental Mine.

1901.—Great Cobar North sunk a shaft 325 feet deep to prove the continuation of the Great Cobar lode.

1902.—Great Cobar: "Naismyth slag-pots introduced; capacity, 2 tons; drawn by horses. Additional air-compressor machinery installed, also new blast furnace."* Great scarcity of water in district owing to heavy drought. Water brought by Government from Warren artesian bore for domestic use. North Cobar prospecting shaft 500 feet deep. Queen Bee and Queen Bee South mines prospected afresh.

1903.—New furnace started at Great Cobar, with a capacity of 300 tons a day. Large furnace of Mount Lyell type purchased. Slag-pots removed by locomotives in trains of six. New main shaft began.*

Occidental erected a Raff wheel for elevation of tailings. Three new slime pits and three solution vats added to plant. The Blue Lode at the Peak yielded good returns.

1904.—"Cobar–Chesney Mine purchased (by Great Cobar); ore smelted with the Cobar; about 27 per cent. being used with the basic sulphides of the latter. Ore-breaker erected; capacity 120 tons per hour. New furnace started; measurement, 17 feet."*

Cobar Gold-mines experienced difficulty upon meeting with copper content in ore. New level opened up at 316 feet. Main shaft down 416 feet.

1905.—Great Cobar: "Option to purchase given to an English company at end of year. Smelting plant—three furnaces—capacity, 250 to 380 tons daily. Samuelson's Roots blower, pressure 22–24 oz. per square inch. Hot blast abandoned in favour of cold under increased pressure."* Great Peak Gold-mine and Queen Bee producing well. Large slimes plant erected for Occidental. C.S.A. discovered large body of lead ore at a depth of 450 feet, under aid from Government Prospecting Vote.

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* Carne, "Copper-mining Industry," p. 238.

Photo. lent by Frank Lean.

Great Cobar in 1874.

Compare with Plate VII.

1906.—Great Cobar: "Mine and associated properties (with exception of Nymagee) acquired by an English company—The Great Cobar (Limited)—for £800,000 cash. The Cobar syndicate's properties transferred being the Cobar mines and plant; Lithgow refinery and electrolytic plant and associated colliery; and colliery and coking ovens at Rix's Creek, near Singleton. New main three compartment shaft, 15 feet x 7 feet 6 inches, being sunk on east side of lode to 1,000 feet level. Barton's shaft, 1,000 feet, equipped with first-motion winding-engine. Large blast-furnace erected; two blowers added to plant. Foundations for three furnaces of large capacity, and for converter plant, begun."* Queen Bee shaft 500 feet deep. New shaft at C.S.A. sunk 250 feet. Square-set timbering employed in this mine to cope with the heavy ground. Main shaft at Cobar Peak Silver-mine 360 feet deep.

1,350 men employed in Cobar mines.

1907.—New plant installed at Great Cobar; 964 men employed in the mine and works. Main shaft at Occidental sunk 221 feet. Small experimental blast furnace erected at Queen Bee Mine. Tinto Mine (Gardiner's blocks) showed good prospects. C.S.A. pursued vigorous policy of development, carried main shaft down to 595 feet, and drove 637 feet along ore body. Cobar Gold-mines erecting an experimental unit of Elmore plant. Great Cobar North main shaft (No. 3) down 613 feet.

1908.—New furnaces in action at Great Cobar. Development of large masses of basic ore at depth of 950 feet in Great Cobar Mine. Developments in Occidental along Nos. 4 and 5 levels (440 and 540 feet deep respectively) very satisfactory; copper being almost absent and gold being in payable quantities. Trial with Elmore vacuum process on Cobar gold ore partially successful. The copper content of the ore in this mine is the serious drawback to its development under the present system of recovering the gold. Gladstone lode prospected. Chesney Mine opened up at No. 6 level.

1909.—Main shaft of Great Cobar 1,094 feet deep. Tinto Mine yielded good prospects. Cobar Gladstone new shaft 219 feet. Rich body of copper ore exposed at water-level. Great Cobar North shaft 1,130 feet deep.

1910.—A new furnace erected for Great Cobar, making four in all. New store, foundry, smith's shop, fitting shop, and carpenter's shop erected. New storage bins in course of erection to hold 6,000 tons of ore. Main shaft 1,150 feet in depth. Deepest working level 1,000 feet. Level being opened up at 1,150 feet. Cobar Gold-mine purchased by Great Cobar during the year, the two being connected by railway. Large bodies of good stone opened up along No. 6 level (700 feet) in the Chesney Mine. Cobar Gladstone made heavy water during sinking of shaft at 200 feet. Tinto main shaft sunk to depth of 530 feet. Good body of basic ore driven on at that level. New vein of promising character found to the east of the 450 feet level in the C.S.A. Mine. New machinery erected at Occidental.

Fresh capital subscribed to Queen Bee; shaft sunk to 700 feet. Good ore exposed in southern drive from 570 feet level. Level opened up at 670 feet.

1911.—Great Cobar opened up level at 1,150 feet, sunk main shaft to 1,250 feet, and commenced to open up Middle lens at that depth. Northern lens at 1,000 feet (No. 10 level) as much as 160 feet in width, with strong development of basic ore on its western side. Eastern portion of middle lens on Nos. 10, 11, and 12 levels of siliceous character, but relatively high in copper. Proposal to concentrate this eastern acid portion of the ore body before smelting. Shaft 1,400 feet deep in 1912.

* Carne, "Copper-mining Industry," pp. 238–239.

The sulphide zone of the Cobar Gold Lode lying between the 325 feet and 425 feet levels, worked in conjunction with the basic ore of Great Cobar. Main shaft sunk to 525 feet depth, and preparations made to open up the lode at that depth.

Chesney Lode opened up to the south at a depth of 800 feet. Area of pipe of rich ore (copper 5 per cent., gold 6 to 8 dwt.) on this level about 2,000 square feet as against 417 square feet on the No. 6 level (700 feet). Erection of plant to concentrate Chesney ore by jigs and mineral separation before sending to the Cobar smelters.

Occidental working sulphide zone. Proposal to slime ore and recover by Filter Process.

Queen Bee developing ground south of main shaft at depths of 150, 350, 570, and 670 feet. Proposal to treat ore by oil flotation process.

Approximate total production to end of 1911.

Copper	95,000	tons.
Gold	460,000	ounces.
Silver	1,180,300	„

Changed Appearance of Country since inception of Mining Operations.

In 1870 a thick forest growth overspread the greater part of the Cobar district. Dense undergrowth and abundant grass of a fair quality were not uncommon in good seasons. This grass and edible undergrowth existed until the rabbit invasion of 1890, or thereabouts. The rodents are reported to have come in millions from the west at that time. They climbed certain trees and shrubs easily, especially the Currant-bush (*Apophyllum anomalum*) and the Mogil or Wild Orange (*Capparis Mitchelli*). Such trees as they could not climb they ringbarked. All kinds of shrubs were eaten by them, even to pine—the pine is said to have killed them in turn. A long and severe drought, ending in 1903, is supposed to have been responsible for the present wonderful reduction in their numbers. An epidemic also at one period considerably reduced their numbers. For miles around Cobar, where once were waving grass lands and charming forests, one now finds but little grass and herbage—no trees worthy of the name are to be seen—huge clumps of dead shrubs are common sights; and appalling dust-storms are not of infrequent occurrence.

The absence of the trees and grass has been ascribed by many to the large discharges of sulphurous acid from the smelters. This, however, is only in part true. It is certain that in Queenstown and Gormanstown (Tasmania), the sulphur fumes from the smelters of the Mount Lyell copper furnaces kill most of the vegetation for miles around. This, however, is an area of enormous rainfall, and the formation of sulphuric acid from the sulphurous acid is responsible for the scene of devastation there. Cobar, however, is a dry region, possessing an average rainfall of 15 inches per annum, and the effects of the sulphur fumes on the vegetation are not as severe as one might be inclined to think. It is a fact that numerous beautiful house gardens exist within a distance of half a mile of the furnaces. In this respect it is in marked contrast with the utter wilderness around Mount Lyell, despite the average rainfall there of 120 inches of rain a year. At Mount Morgan (Queensland) also, and at a distance of less than half a mile from the huge smelters a beautiful flower garden is maintained. This, on the other hand, is in a region of moderate rainfall.

Photo. Great Cobar, Ltd.

Great Cobar Mine in 1911.

Three causes appear to have contributed towards the destruction of the timber, shrubs and grass in the Cobar district; one is overstocking; another is a long succession of dry seasons which succeeded the rabbit invasions and did not disappear until the year 1903. The salt-bush, emu-bush, currant-bush, and other edible plants have been eaten out in a great measure, and young growths of such fodder plants as currawong, kurrajong, salt-bush, and emu-bush, are browsed off. If the country be "spelled," and if a succession of good seasons should come again, the saltbush and edible shrubs would return, despite the sulphur fumes. The third is the onslaught made upon the forest growths for smelting purposes.

Health.—Cobar is dreaded by many people on account of the prevalence there of typhoid fever during the summer months. Whatever typhoid exists there does so simply as a result of the ignorance of the laws of health on the part of the Cobar public, as the climate itself—with the exception of the months of November, December, January, and February—is quite healthy. Even during these months the climate, although severe, is not deadly. In the early days of the field there was little or no sickness; men worked hard; they had none but the simplest of fare, and they had abundance of fresh air. All drank out of one tank; that tank was formed in the lowest point in the settlement, and received the drainage from the camps around, yet there was no fever.

At a later date two tanks were made half a mile lower down Linsley-street Creek than the original one. These tanks received the drainage from the town, nevertheless there was no sickness. At a later date a reservoir was formed 2 miles to the north-east of the town. Into this tank no town drainage could enter, and the town was still healthy. The present water supply is distant 4 miles from the township, and its catchment area is kept as clean as possible with the limited municipal staff. It has been during this period that the typhoid has given to Cobar its dreaded name.

It would seem that it is a sort of indifference to the laws of hygiene on the part of the Cobar public, which has allowed typhoid, when once admitted, to secure a firm footing. The arid and desiccating climate can hardly be held responsible for the trouble. Trees are ruthlessly cut down; few trees are planted in the streets and house-yards to act as scavengers; the waste water of the houses, with few exceptions, festers on the ground, there being neither natural streams to carry it away nor vegetation (such as pepper-trees, lilies, and grass) to absorb it. Before throwing the responsibility of the spread of dangerous fevers on to the Government Health Department, a people should do a little individually towards maintaining healthy conditions. Take, for instance, the pepper-tree. This graceful and beautiful plant, when once well started, thrives splendidly in Cobar, both in the main streets and in the house-yards. It is, moreover, a wonderful scavenger, sending its roots for long distances in search of nutriment in this dry country. If the streets and house-yards were planted with these trees, and the waste water from the bath and house were placed near the roots of the trees (the ground being kept loose), there would be few of the noxious smells that arise from festering waste. Lilies and grass-plots are also useful in absorbing waste water.

Population.—Mr. Neil Morrison gives the number of electors on the roll in the Cobar District at about 3,175. The 1911 census gives the population of Cobar at 7,070 people.

Smelting.

The basic copper ores of Cobar have been smelted with the auriferous acid ores of the Chesney and The Peak since the year 1904, and with those of the Cobar gold mine since August, 1910.

Great Cobar has now four furnaces and three converters in use. The gold ores of The Peak are carted to the Occidental railway platform, and conveyed thence by rail to the Great Cobar smelters. The Chesney ore is conveyed by a travelling belt to the ore hopper for trucking. Worthless material is rejected in part by hand-picking while the ore is in transit. Thence by train and electric tram these acid ores are conveyed to the ore bins.

The ore of the Great Cobar is hoisted to a high brace, thence through two crackers, thence over a wide travelling belt, the gangue being removed in transit. From the belts the ore drops into large bins, from which it is removed to the storage bins by electric cars. The Chesney Peak and Cobar Gold acid ores, as also the coke and first matte, are brought to these bins.

Sampling is carried on automatically, a portion of the ore being conveyed to a McCully crusher. The ore is then reduced in size and continually reduced in amount in a definite manner. The rejects from the sampling pass into a small bin.

The charges are weighed and sent in loads of four 2-ton side-tipping trucks along an elevated track to the feeding floor.

The water-jacketed smelters are four in number, and their longer measurements are in alignment. The feed doors of the furnace open by sliding upward, and the furnace is fed by side-tipping the trucks. [See Plate 31.] The smelters rest on brick and concrete bases. The water-jackets themselves are of mild steel set up in two tiers, the height of the two combined being 20 feet and the water space being 5 inches. Three of the smelters possess each a single settler arranged between the smelters, but to the fourth smelter, which was put into commission at the beginning of 1911, one pair of smaller settlers was attached. The larger settlers are 18 feet in diameter and about 4 feet 6 inches deep. The silica fire-bricks with which they are lined, however, reduces their working diameter to 15 feet and their depth to about 2 feet. The smaller settlers are about twice as long as they are wide (9 feet by 18 feet), and are elliptical in plan. A continuous overflow of slag is maintained from the settlers to the slag-pots. The general size of the large slag-pots is 25 tons. (Plate 9.) The dumping of the slag is carried out by an electro-locomotive and by motor.

Three 15-ton converters are in use.

It was the intention of the management when installing the present smelters to carry out one smelting operation only, and then to reduce to blister copper straight-away in the converters. That, however, was found not to be the most economical method of working, and at the present time the smelting is carried out sometimes in two operations before transmission to the converters. If, upon tapping, the matte is found to be of low grade, it is cast into moulds outside the smelting-shed, and conveyed to the ore bins, for second smelting, but if of sufficiently high grade it is at once tipped into the converters. Ten-ton ladles are used in this work, which are hoisted and tipped by a 40-ton travelling electric crane.

In making up the first smelting charge the ore of the Great Cobar (known locally as green ore) is mixed with Chesney, Cobar Gold, or Peak gold ore. The percentage of coke employed is fairly high, as may be seen by a reference to the composition of the typical smelting charges herewith reproduced. No limestone is used in the ordinary charge, but when the settlers are crusted, a

Photo. Great Cobar, Ltd.

Boilers, Great Cobar Mine.

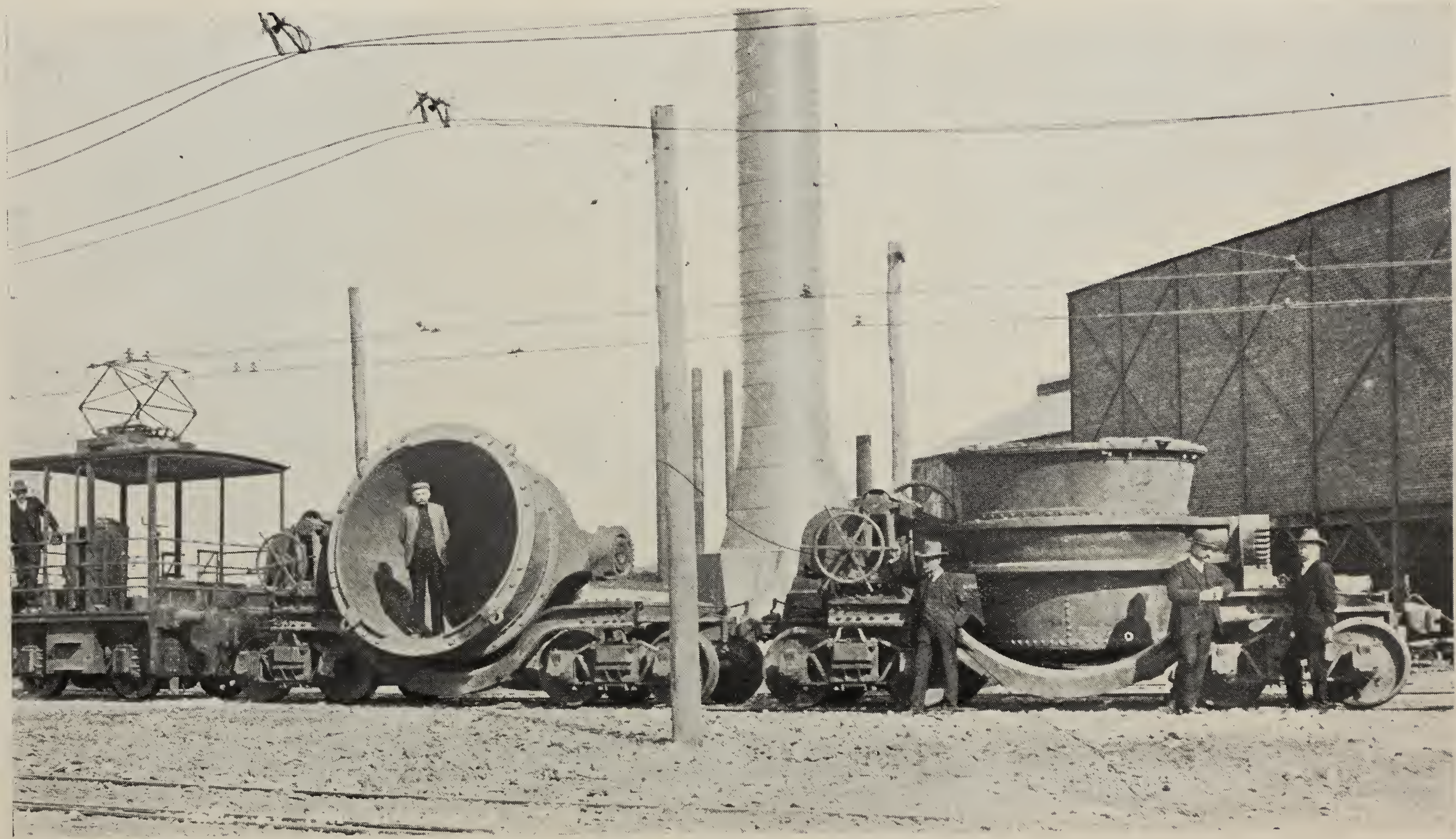

Photo. Great Cobar, Ltd.

25-ton Slag Pots, Great Cobar Mine.

little limestone is added gradually to successive charges so as to dissolve the crust, and thus preventing the clogging of the settler by downward growth of the scum.

A run is made for a bisilicate slag ($RO + SiO_2$). The action of the alumina does not appear to be clearly understood. About ·18 to ·25 per cent. of copper gets away in the slag from the first smelting, and about ·25 to ·40 per cent. copper (depending upon the grade of the matte) during the second concentration.

During the year 1910 the first concentration produced matte containing from 15 to 20 per cent. copper, and in the second concentration a matte from 27 to 38 per cent. copper. During the same year the grade of the matte fed at times into the three 15-ton convertors appeared to be extremely low. Since 1910, however, these difficulties in bringing the matte up to a fair grade before introduction to the smelters appears to have been overcome.

One of the most satisfactory charges employed in 1910 for the second smelting was as follows:—

Great Cobar (green ore)	6,400 lb.
Chesney	1,500 ,,
Peak	600 ,,
Matte	4,000 ,,
Bourke (Cobar gold)	1,500 ,,
Slag	4,000 ,,

During August, 1911, a typical first smelting charge consisted of—

Great Cobar (green ore)	6,600 lb.
Fort Bourke (Cobar gold)	2,400 ,,
Coke	800 ,,

When Chesney ore is used instead of that from Fort Bourke 200 lb. more are used than in the case of Fort Bourke ore, and in that case a reduction of 200 lb. is made in the Great Cobar ore.

A typical concentrating charge in use during August, 1911, was:—

Matte	3,200 lb.
Fort Bourke ore	2,000 ,,
Converter slag (aver. 1·5 per cent. Cu)	1,300 ,,
Cobar sulphide ore	2,000 ,,
Coke	650 ,,
	9,150 ,,

The ingot copper is forwarded to Lithgow.*

The following assays of dump slag and converter slags, representing averages taken during certain periods in 1911, may be of interest:—

Dump Slags.

FeO	50·00 per cent.
Insol	40·00 ,,
Al_2O_3	6·50 ,,
Cu	·25 ,,

Converter Slags.

FeO	59·40	59·90
SiO_2	31·30	29·90
Al_2O_3	7·70	6·20
Cu	·96	1·60

Plate 10 is the flow sheet as in use during 1911.

The blister copper is taken to Lithgow,* 368 miles distant, to be refined by electrolysis. Prior to the establishment of the electrolytic works the bismuth content in the Cobar copper had proved a source of trouble to the management.

* Refining dispensed with close of 1911.

The Queen Bee Smelting.

"The reverberatory plant embraces four reducing and one refining furnaces of a capacity of about 70 tons per week each, one being occasionally worked to 100. The first run matte averages 40 to 42 per cent. copper.

"The small blast furnace, running on the best grade ore, with limestone and ironstone fluxes, averages about 11½ tons per day, producing matte of 31 per cent., the charge being :—

Coke	100 lb.
Raw sulphide...	350 ,,
Slag	120 ,,
Limestone	150 ,,
Ironstone	50 ,,

"The coke and fluxes being slightly increased when slag runs thick."*

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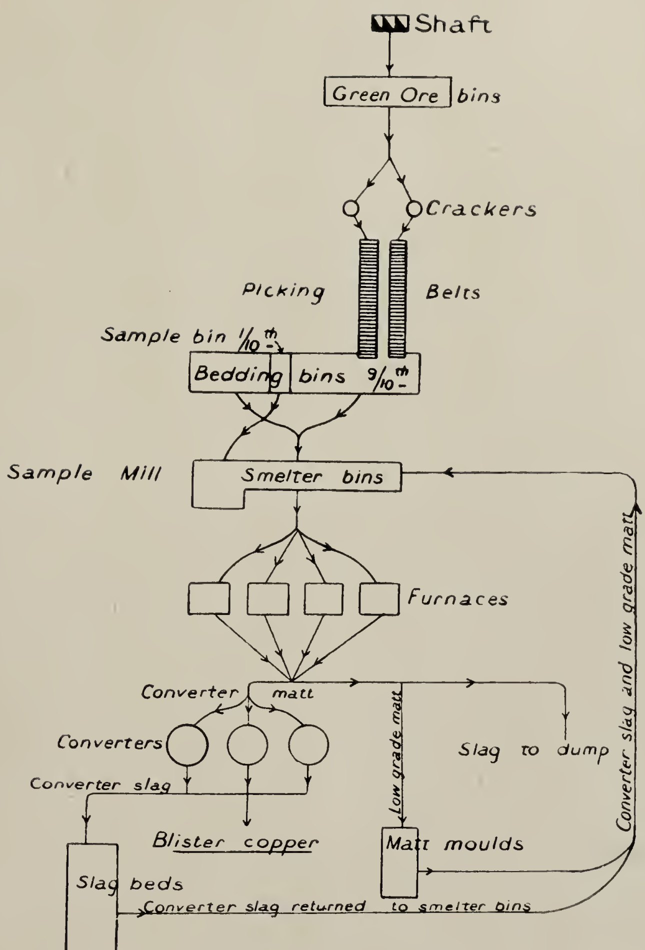
* Carne, "Copper-mining Industry," 1908, p. 260.



Flow Sheet, Great Cobar, 1911.

Chapter II.

PHYSIOGRAPHY.

Drainage System.

The main river of the district is the Darling, which ultimately enters the sea near Adelaide, after junction with the Murray River. A portion of the Cobar drainage is toward the Darling, directly by way of Sandy Creek, and a portion of it flows eastwards into Yanda Creek, which in turn enters the Darling between Louth and Bourke. The country lying to the north-east of Cobar is drained by the Bogan. During good seasons, the Darling River is a magnificent stream, but the Bogan is frequently only a mere chain of waterholes, and useless as a highway. A peculiarity of the streams of this large district is that the great majority of them cannot keep their channels open. Even the Darling, which maintains itself as a stream the whole year round, flows in a wide plain of alluvium, the rock structures being exposed only in very few places along the channel.

The Yanda and Sandy Creek systems, which take their rise in the Cobar district itself, are nothing but long stretches of broad and flat alluviated valleys, in which water only flows during rare periods of heavy rain. The basal portions of the valleys are frequently occupied by alluvium, sometimes as much as several miles in width, along which it is only possible to locate the path followed by flood-waters by a broad belt of bimble-boxes, undergrowth, and herbage. The alluvium of these Cobar valleys is very shallow, and the water in interflood periods apparently creeps under the alluvium itself. Such streams, then, appear to have been building up, instead of degrading, their courses during a considerable period of time.

The towns of Bourke, Louth, and Wilcannia lie on the Darling River. The first-named of these settlements is 100 miles north of Cobar. Louth is 80 miles to the north-west, and Wilcannia 170 miles to the west-south-west of Cobar by road. Nyngan, a town on the Bogan River, lies 84 miles east by rail.

Relief.

The whole of this great district is a plain of erosion. It must not be confused with the great alluvial plains which bound it to the west, north, north-east, and east, and under which it passes with unappreciable dip. Thus, the country descends gradually to the Darling to the north, falling from 800 feet above sea-level at Cobar, to 350 feet at Bourke, in a distance of 90 miles, and westwards in about 150 miles to Wilcannia, 300 feet above sea-level. The one is an alluvial plain, whose present surface at least is of recent age ; the other is a much older plain of erosion, now warped by earth forces, and covered in part by the river alluvium. The one passes vertically downwards from alluvium to horizontally-bedded Tertiary, Cretaceous, and Trias-Jura sediments, the whole, in places, attaining a thickness of 3,000 feet, as in the Moree district, and unconformably overlying the contorted Palæozoic rocks ; the other is a plain formed out of the Palæozoic rocks themselves, upon which a thin mantle only of waste and alluvium has collected.

The otherwise monotonous sweep of the Cobar River is relieved, however, by two types of profiles, namely, the general undulations which characterise the surface of the plain itself, and the small ridges and residuals (*Frontispiece*) which overlook the general level to which the crests of the plain undulations rise. The highest of these residuals are Mounts Boppy, Drysdale, and Nurri, The Peak, and the Biddabirra Hill. The Peak is 200 feet above the surrounding plain, and is distant 5 miles from Cobar; Mount Nurri, 500 feet, and distant 20 miles; Biddabirra Hill, 200 feet, and distant 10 miles; Mount Drysdale, 350 feet, and distant 22 miles; Mount Boppy, 400 feet, and distant 28 miles. In all these, the heights are those above the surrounding plain, and the distances are those from Cobar. Fort Bourke is the most prominent point in the neighbourhood of Cobar, and it rises 150 feet above Cobar. Further west and north-west, towards the Darling, the Devonian outliers of quartzite rise to somewhat greater heights above the plain level. Of these, Booroondarra is the highest.

The residuals of the plain are rarely of any length, with the exception of the belt of elevated country between the Queen Bee Trigonometrical Station and the south-end of Mount Nurri. Here, a mass of crumpled, crushed, and sheared conglomerates and sandstones stands up in relief from its setting of slates for a distance of 10 miles. The main ridge is, nevertheless, inconspicuous, except at its northern and southern ends, where the rocks rise about 200 and 500 feet, respectively, above the plain.

Approaching Cobar from the Bee Mountain, the Peak is the residual next in size. (Plate 11.) It consists of a cone and lower ridge, carved in heavily faulted sandstones, surrounded by slates. To the north and west of The Peak lies the long and low ridge upon which outcrop the Occidental, the Young Australian, the Mount Pleasant, the Chesney, the Cobar Gold, and the Fort Bourke lodes. Further to the west and north lies the insignificant Elouera, or C.S.A., Hill.

It may be noted that each residual is associated with strong dislocations. The planes of dislocation are approximately parallel, but the intensity of movement appears to have been rather local, the maximum strain passing to the west with increasing progress to the north. The hills thus are arranged *en echelon*. Induration of country by the introduction of abundant silica and iron along these planes of rupture probably has been responsible in great measure for the occurrence of the residuals. In a measure also the residuals are due to the presence of relatively dense sandstones which have been faulted against the slates and other sandstones. In the processes of crumpling and faulting their bedding planes have frequently become almost obliterated, and thus they have become still more resistant to the action of erosion.

Mr. Carne refers to these residuals, and points out the preservative action on them by the introduction of silica and iron.*

He draws an important deduction therefrom :—

> "The elevated areas at Cobar are the direct result of mineralisation, the indurating influence of which has rendered them less amenable to subærial disintegration and degradation than the surrounding country. This feature probably lessens the prospect of any extensive metalliferous deposits occurring in the level country."

Below these residuals, which possess a prevailing strike of about north 20° west and an offsetting to the west as one proceeds north, there are the valleys which break up the general surface of the plain. From the top of any one

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* "Copper-mining Industry," 1908, p. 231.

Photo. T. F. Lean.

The Peak from the North-west.

of the long and almost imperceptible rises which form the valley walls the whole country appears somewhat like a huge sheet of corrugated iron, the corrugations representing the valleys, the disposition of the corrugations being more radial than parallel, but the valleys being relatively broader and possessing much more gently sloping sides than the corrugations of ordinary roofing-iron. All the valley floors are alluviated, and all the valley sides are covered with a decided waste sheet.

With very few exceptions the residuals which rise above the even valley crests are covered with a waste sheet. The exceptions are the upper portions of Mount Nurri, the Bee Mountain, The Peak, and the Biddabirra Hill at the Amphitheatre. A few outcrops of sandstone are also visible on the Fort Bourke and Chesney hills. At The Peak the bedding planes can generally be made out, but at the Bee Mountain and Mount Nurri the bedding planes of the sandstone have been almost obliterated by the alteration which the rocks have undergone. It will be readily seen from this statement that the geologist is obliged to depend for information as to dips and strikes of rocks upon mining excavations.

It is evident at a glance that some decided physiographic change has come over this district in recent geological time. Certain it is that the subradial valleys which diversify the plain were excavated by running streams and their channels at that period were kept open by the streams. Certain it is also that at the present time these recent rock-channel bases are becoming choked up. The present streams are only wet-weather types, and for years at a time they die away in the sand without flowing at the surface. Moreover, the heaviest rains of Cobar are recorded mostly as local thunderstorms, which have but slight influence in keeping open the main drainage channels.

The simplest explanation of the physiography is that Cobar has remained above the sea-level since the Devonian period, and that it has slowly risen and been gradually denuded, while the adjacent areas now covered by the red and black soil plains (and other material, such as Cretaceous and Trias-Jura sediments), have sunk to form the enormous artesian basin. Plains of erosion have in all probability been cut out of the Cobar area corresponding to each period of sedimentation in the adjacent artesian basin. The present plain, dotted over with siliceous residuals, and diversified by broad and shallow valleys, separated by almost insignificant ridges, represents the last of these plains of erosion formed in the Cobar area. Its age is unknown, but it is considerable, because of its almost unbroken surface.

The shallow valleys diversifying the plain were formed after an uplift of the area at a time when the rainfall was enabled to keep the channels clear, and therefore to abrade the channel bases and sides. Then came the formation of the Eastern Highlands of Australia by the upheaval of the eastern portion of the old plain of erosion. The effect of this uplift was to increase the precipitation on the eastern seaboard, but to decrease that of the interior of New South Wales, by presenting a barrier to the winds from the sea. The effect of this has been to reduce the Cobar supply, and at the present time the precipitation is insufficient to keep the channels open.

While this explains the partial silting-up of the local stream channels such as those of the Yanda and Sandy Creek systems, nevertheless it explains, only in part, the origin of the great alluvial plains which surround the Cobar district to the west, north, and east. These are due in great measure to the denudation of basic lavas which deluged the New England and associated areas in Tertiary time, and which were elevated at the same time that the present eastern highlands were formed. The streams of the Darling system commenced to flow much more swiftly as soon as the eastern highlands were formed, and thus were enabled to carry heavy loads of stream *débris*. This *débris* consisted of the waste derived from basalt and other rock types. Upon reaching the plains at the feet of the highlands, however, their power of transportation became much reduced, and they dropped their loads both along the stream courses and on the associated country. Thus the river alluvium of the Darling system appears to have been formed. See also the report of the Writer on the Forbes-Parkes Gold-field, Mineral Resources No. 13, 1910, pp. 37–38.

Arid Climate Weathering.

A point deserving attention is the influence of the climate of Cobar upon the more superficial rocks. The climate of the district under consideration may be described as sub-arid, because its average rainfall is only about 15 inches a year. The maximum shade temperature recorded has also exceeded 118 degrees Fahrenheit. In addition to this, for months at a time, the shade temperature rarely falls below 90 degrees in the middle of the day; and hot, drying winds are common in the more central portions of the continent.

The immediate result of this desiccating action is to induce the underground water to rise to the surface much as a biscuit or a piece of loaf-sugar will take up water in proportion to its condition of dryness. Upon arrival at the surface, however, the arid atmosphere will evaporate most of the water, and any material held in solution will be precipitated at, or near, the surface upon the evaporation of the water. These circulating waters reveal the presence of sulphates, carbon-dioxide, alkaline carbonates, and other solvents. It might naturally be expected thus that the more soluble constituents of the rocks would be brought up in great measure to the surface.

The accompanying analysis of a typical Cobar slate, made at the Departmental Laboratory, indicates the material available for solution in the great belt of slates accompanying the mining zone:—

891–11.—Clayslate ("X 17") from near the Peak.

Moisture at 100° C.	0·33	
Water above 100° C.	3·10	
Silica	62·12	
Alumina	18·90	
Ferric oxide	1·75	
Ferrous oxide	4·41	
Manganous oxide...	0·05	
Lime	0·78	
Magnesia	2·72	
Soda	0·29	
Potash	4·86	
Titanium dioxide...	0·75	
Phosphoric anhydride	0·14	
Sulphur trioxide	absent.	
Chromium sesquioxide	do	
Baryta	0·04	
Strontia	trace	Spectroscopic reaction only.
Lithia	do	
Vanadium oxide	absent.	
	100·24	

A trace of soluble chlorides present.
(Analysis by Mr. W. G. Stone.)

Other analyses of slate supplied in this report (page 51) also show that soda, potash, lime, iron oxides, magnesia, and other more or less soluble contents, are generally present throughout the Cobar area. If arid conditions then had caused a precipitation at and near the surface of the material derived from the more superficial rock masses the minerals revealed by the rock analyses should be those which would characterise the superficial precipitations. In addition to this the rocks underlying the superficial deposits should show a proportional absence of minerals so precipitated. In areas of strong compression, where the rock dips are high, one would also expect the superficial accumulation to show a tendency to follow the strike of the beds; thus, for example, a deposition of calcareous tufa should characterise the outcrops of certain beds rather than those of others. It will be advisable here, then, to compare this suggestion with the known facts of occurrence in the Cobar district.

From the Rookery to the Mallee Tank, a distance exceeding 10 miles, sandstones and fossiliferous compact limestones of Silurian age occur in patches. They rarely show defined outcrops, but occur mainly as scattered boulders of spheroidal shape. With them are associated long and low outcrops of a fine-grained and sub-translucent quartzite possessing a thin non-translucent crust. The quartzite has a cherty appearance, and breaks with a subconchoidal fracture clean across the individual grains. These large deposits of quartzite, at first sight, are suggestive of outcrops of Silurian rocks, but excavations beneath them for fireclay reveal the quartzite as a relatively thin horizontal mass overlying a mass of soft fireclay. The limestone analyses from this locality yielded returns of 99 per cent of calcium carbonate. The quartzite thus may be explained as a solid deposit of siliceous material related in some way to the presence of the calcareous and arenaceous rocks associated with them.

Frequently also, large deposits of limonite occur as "blows" and in long lines following the outcrops of the Palæozoic sediments. In each case they have been prospected for copper, gold, and silver. In the majority of cases, however, the underground working in such mining operations reveal the presence of rocks almost devoid of ferruginous material. Fireclay often underlies these ironstone masses. Moreover, the fireclays may be seen to form part of the same steeply-inclined beds of which the limonite forms the cap. The iron oxide also not only frequently forms a capping to the slates or other rock types, but there is a gradual transition from the underlying fireclay [slate or slaty sandstone altered *in situ*] to the ironstone above, the bedding planes being specially charged with iron oxides. This constant phenomenon of ironstone cappings passing gradually downwards into non-ferruginous slates and sandstones as the beds of sediments are followed suggests the transference of material from slight depths to the surface by capillary attraction.

Furthermore, the coating of calcareous tufa so commonly formed on the surface of the Cobar slates, and the large nodules of magnesite which at times occur so plentifully as a superficial replacement of, and deposition upon, the slates may be explained in the same way. An examination of the analyses of slates supplied in this report shows that the materials from which the superficial deposits have been formed are all contained in abundance in the rocks themselves, and, moreover, prospecting operations indicate that the abundant superficial deposition of the mineral is counterbalanced by a corresponding absence of such minerals in the rocks at slight depths below the surface. (See analysis of underlying fireclays, pp. 55 and 62.)

Another point which may be dealt with under the head of weathered products is that concerning the black and reddish soils of the district. The products of weathering *in situ* in the Cobar area are reddish in colour, while the material of the river alluvial, namely, that material which is subject to periodical floodings by water, is composed of stiff, adhesive, black clay. The red colour of the "waste sheet" appears to be due in great part to arid weathering, while the "black soil" appears to be due to the combined action of basic rock constituents (such as the finely-divided fragments of dolerites, basalts, and andesites) of organic material, and to the presence of water.*

[See also Forbes-Parkes Report by the Writer, Dept. Mines, N. S. Wales, Mineral Resources, No. 13, p. 14.]

A blackish colour appears to represent the presence of carbon, while red soils and rocks appear to be due to peroxidation under conditions of heat maintained during considerable periods of time.

If then the black-soil plains should become dissected in turn and the upper portions thus remain unflooded for years together, such old black-soil plains would gradually tend to become reddish in colour by peroxidisation of the contained iron. Similarly also, the reddish-sand plains covered with mallee and spinifex—such as occur at Shuttleton and Mount Hope—may be explained as arising from the peroxidation of the contained iron under a hot sun or sub-arid or arid climate not subject to periodic and sustained flooding.

Another point calling for attention is the peculiar colours possessed by the Cobar slates near the surface. Below water-level the slates are invariably dark and bluish or greenish in colour while at the surface they occur in sub-parallel bands which possess yellow, white, grey, red, purple or chocolate tints.

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* See also Mr. R. H. Cambage, Aus. Ass. Adv. Science, Adelaide Meeting, 1907, p. 476.

Chapter III.

GENERAL GEOLOGY.

Rocks.

General Statement.

The rocks all fall within the limits of the Palæozoic Group. Silurian and Devonian types are both represented. Pre-Silurian rocks are also probably represented. Some of the Silurian and Devonian rocks appear to have been intensely altered along relatively narrow north and south lines. It must be distinctly understood that the classification adopted in this the first portion of the Report dealing with the Mineral Resources of Western New South Wales, is merely tentative, and only after the detailed survey of the Canbelego and Nymagee areas has been completed can any opinion concerning our Central-Western geology be confidently expressed.

The Silurian System comprises conglomerates, sandstones, claystones, slates, and limestones; the Devonian consists of enormous thicknesses of such types as conglomerates, sandstones, quartzites, shales, and false-bedded argillaceous sandstones interbedded with thinner belts of conglomerates.

Two orthoclase porphyry "pipes" have intruded the altered Silurian sandstones of the Bee Mountain.

Palæozoic Sedimentary Rocks.

The section in general.

The strike of the Cobar Palæozoics varies from north and south to north 45 degrees west. To the east of the town of Cobar the rocks are very much crumpled. Near the lodes the prevailing dips, as observed, are westerly, while the greater portion of the Devonian lying to the west of the town has an easterly dip. The average angular value of the dips in a section 20 miles in length taken across the strike exceeds 40 degrees; and the total thickness of the Palæozoic sediments represented is thus of great thickness. It is possible that isoclinal folding of beds may occur in this crumpled mass, especially to the east of Cobar, and this may account in some measure for the apparent enormous thickness of these rocks in the Cobar district. There are, however, several distinct types of rocks, which are to be found in an east and west traverse of the district, and these do not appear to be duplicated. Thus, from 8 to 10 miles east of Cobar a dense series of sandstones and shales occurs; between the 3-mile and 7-mile mile pegs the type rocks are cherts, sandstones and chocolate and white shales. To the west of these lie the argillaceous sandstones and slates of Cobar itself, and to this succeed Devonian quartzites, sandstones, claystones, chocolate, yellow, and shales.

Strong strike faulting is indicated in the district and the apparent thickness of the beds in this way may be partly accounted for.

Definite results have not yet been obtained in regard to some of the main rock relations, because of the presence of an enormous waste sheet, the absence of natural exposures, and because of the folding and dislocations to which the rocks have been subjected.

The Weltie Beds.

General Character and Distribution.

The best exposures of this group are to be found in the railway cuttings from 3 to 15 miles east of Cobar, especially at points 7 and 9 miles east of Cobar respectively. Even on this line only a very imperfect idea of the rock sequence can be gained. Along no other line are there any noticeable outcrops at which dips and strikes could be taken. The junction of the Weltie beds with the Canbelego schists on the east, with the Mallee Tank beds on the west, and the Cobar Series, also on the west, has not been found.

No geological section of this great mass of sediments could be made with any pretence to accuracy, owing to the discontinuity of outcrops. All that can be certified for this group is that the members are much contorted; that they possess high dips, and that the mass is of enormous thickness.

Three types of sediment are predominant:—

(*a*) Argillaceous and strongly cross-bedded sandstones of white, grey, yellow, brown, and reddish colours.

(*b*) Tough cross-bedded shales and claystones of white, grey, yellow, purple, and chocolate colours.

(*c*) Jointed and thinly-bedded cherts of greyish and brownish colours.

Petrography.—The sandstone is not thickly bedded, but is usually made up of delicate bands. Cross-bedding is an exceedingly common feature. The bands of the cross-bedding, however, are not usually inclined at such steep angles to the true bedding-planes as are those of the Triassic sandstones in eastern New South Wales, but frequently pass insensibly into the principal plane of deposition. The majority of the beds rarely exceed 1 foot in thickness, and these in turn are divisible into layers averaging an eighth of an inch in thickness. The sandstone is not hard, and has a decided tendency to break along the planes both of true and false bedding. In the whole group no coarsely-grained sandstone was observed. The common constituent materials are exceedingly fine grains of quartz, clay, ironstone, and mica flakes. The quartz grains appear to be of either granitic or quartzitic quartz, and are fairly well rounded. The mica is of the silvery white variety, and it is owing to its arrangement that the rock separates so readily along its bedding-planes. The cementing material consists of clay from which the iron oxide has been removed in great measure. As with all of the Cobar rocks, the outcrops of these sandstones are ferruginous. Sinking to a depth of a few feet, however, from the surface, the underlying sandstones are seen to be very light in colour. The reason is that in this arid climate the moisture is drawn to the surface by capillary attraction, and there drops any material it may have had in solution. In this process the beds below the surface become lighter in colour in proportion as their ferrous content is drawn to the surface. As a general rule, a strong red or brown outcrop for the sandstones is indicative of a grey or white colour for them underground.

The Shales are chocolate, purple, red, yellow, grey, and white in colour. They are very fissile, breaking out along the bedding planes into the finest laminæ, sometimes not more than one-hundreth of an inch in thickness. Although appearing as very weak structures in the railway cuttings, nevertheless, they are somewhat difficult to remove in any but small fragments owing to a certain definite degree of toughness possessed by them. They alternate with the sandstones and may attain a thickness of as much as 100 feet between two layers of sandstone. Mica in silvery white spangles is a common constituent. There is no trace of cleavage either in the shales or the associated sandstones. At first glance the decided fissility of the shales is strongly suggestive of cleavage, but upon comparing the shales and the sandstones it is at once evident that there is no trace of true cleavage because the planes of fissility are absolutely parallel to the planes of bedding in the sandstone; the planes of lamination follow the contortions of the sandstone beds; and the shales, moreover, have not been compacted into slates.

Petrography and Analysis.—The shales are finely laminated, and of chocolate, red, brown, yellow, and white colours as in the Weltie sandstones, but they show much more contortion than the more eastern members.

The sandstones possess ferruginous outcrops which pass into brown and creamy yellow masses a few feet below the surface.

The Cherts.—These sediments are intimately associated with the weak sandstone and shale series with which they are interbedded, a series of well jointed and well bedded thin layers of cherts being immediately succeeded above or below by fairly impervious shales and claystones, the shales showing no chemical alteration.

At the surface the cherts appear as small pieces of brown or red ironstone, or as smooth and small polished yellowish-brown ironstone pebbles. There is nothing in the nature of the superficial deposits of loose ironstone pebbles to suggest the character of the sediments below. Upon breaking open these ferruginous clay nodules or pebbles they are often found to possess a flinty kernel. These represent the incomplete reduction of the flinty beds to ironstone at the surface. Immediately under the loose surface accumulations the rock reveals its flinty nature, but only as kernels; the numerous joints into which the rock is broken up having acted as planes from which the ferruginous solutions have eaten their way into the interjoint areas.

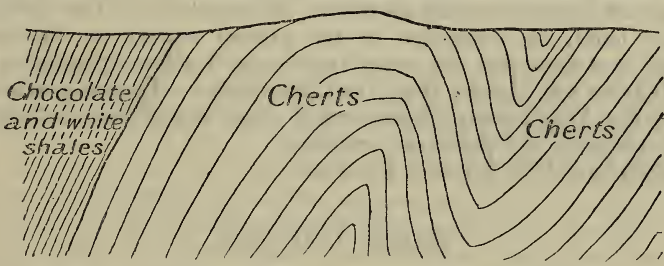

Fig. 1.

Detail of section of Weltie Beds, illustrating the intimate association of crumpled but *well-bedded* cherts, with weak and uncleaved shales and sandstones.

Another peculiar form of weathering is that whereby the translucent and flinty appearance gives place to a whitish-grey colour, throughout which, at times, may be discerned flat ellipsoids of chocolate-coloured ironstone.

In the railway cuttings the rock is seen to consist of thin beds of translucent flinty material, generally highly crumpled (Fig. 1). The bedding planes are distinct, and there is no trace of cleavage either in the cherts themselves or in the associated sandstones and shales.

The texture is excessively fine and cannot be resolved with the most powerful lens. Under the microscope no signs of structure have been observed.

The joints are very numerous, causing the flint to break into very small parallelopipeds. Conchoidal fracture is not uncommon.

Conditions of Deposition.

With the exception of the sandstones, all the sediments of this series are of very fine texture and are evenly bedded. The evidence is that they were deposited in a large water body of moderate depth. The sandstones point to more shallow conditions. The region from which they were derived appears to have been of gentle relief. With regard to the origin of the flints or cherts, no signs of organic or clastic structures have been observed by Mr. G. W. Card and Mr. W. S. Dun in thin sections of these rocks. The Writer is of opinion, in the absence of any direct evidence of the origin of these cherts, that the explanation supplied by Van Hise with regard to the whetstones of Arkansas is the most feasible to adopt, as a tentative explanation of the Weltie Cherts.

> "Another very interesting occurrence of chert is that of the whetstones of Arkansas. These are associated with clay shales rather than limestones. They were regarded by Griswold as fragmental, and therefore not belonging to the class of cherts at all, but to the novaculites. But Rutley has shown that these rocks contain no evidence of Clastic origin, and have all the characteristics of cherts. He regards them as replacement deposits of dolomite or dolomitic limestones. As this chert formation is somewhat persistent, and is between shale beds which are rather impervious, I am inclined to believe that it may be largely an organic precipitate, although now completely recrystallized, so as to be composed of perfectly-fitting granules of quartz." *

Age and Correlation.

This series has been classed here as Devonian because it shows no structural affinities with rocks of known Silurian age in the district. On the other hand, the extension of the present survey to Nymagee and Canbelego may show that the series under consideration represents a portion of the Silurian less altered than the Cobar Series. Typical quartzites such as those in the Amphitheatre Series west of Cobar are absent; but claystones, shales, sandstones, and cherts are common.

No fossils have been found in the series.

Mallee Tank Beds.

General Character and Distribution.

This name has been given here provisionally to a series of highly-folded rocks which adjoin the Weltie Beds on the east and the strongly metamorphosed Cobar Series to the west. The type occurrence is in the vicinity of the Mallee Tank and Conqueror Mines, about 11 miles to the south-west of Cobar; hence the name given to the beds.

Conglomerates occur here, associated with sandstones, quartzites, breccias, claystones, and limestones. Eight miles farther to the south, along the strike of the rocks, the association of rocks is limestone, sandstone, and claystones. To the north-east of this belt lie the great masses of sandstones, shales, and cherts known as the Weltie Beds, and the Nyngan Road cherts and shales. Mining operations furnish sections of the limestones, conglomerates, and sandstones of the Mallee Tank, the rare and small rock outcrops yielding but little real information concerning the nature of the rock masses below.

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* Van Hise, "Metamorphism," 1904, p. 853.

Rookery Limestones and Associates.

General character and deposition.—This name is given to a group of rocks typically developed at the Rookery, distant 22 miles south-west of Cobar. No natural sections were observed, the limestone occurring as insignificant outcrops and as scattered loose boulders along a line from the Rookery to the Mallee Tank, a distance of 12 miles in a direction north 30° west. In the paddocks near the Rookery Head Station, limestone boulders frequently outcrop in association with quartzites, fireclays, and calcareous claystones. The area on which the limestone outcrops is one of very gentle relief, consisting partly of alluvium, partly of gravelly material covered with dense mallee scrub, and partly of very gently undulating ground dotted with limestone boulders and masses of quartzite.

Small excavations have been made a few miles north of the Rookery Head Station, and in these the limestone may be seen to occur either as thin well-defined beds or as a massively bedded blue rock. In one pit the massive limestone was observed to dip in a south-easterly direction at an angle exceeding 50 degrees. This outcrop was more than 225 feet measured across the strike. In another pit, about 8 chains east of the one just described, the limestone was well bedded, and possessed a north-westerly dip, having a value of about 45 degrees. This exposure exceeded 200 feet measured across the strike. Evidently the exposures in the two pits represented the western and eastern limbs of a syncline.

At the Mallee Tank itself the limestone, which is almost undoubtedly of the same age as the Rookery example, was discovered by mining operations.

Associated with the limestones are augen sandstones similar to those of the Cobar Series.

Petrography and Analyses.—The limestone of the Rookery is a bluish-black and well-bedded rock. The massive variety breaks with a conchoidal fracture. The texture is very fine. Calcite is almost absent, except in fossil remains, which are somewhat abundant. The bedding planes are well preserved, and the limestones split readily along them. These surfaces of separation are not straight, but have the appearance of gentle undulations in places, and narrow and irregular zones of discoloration are associated with the bedding. Silica is almost absent, the limestone being pure and well adapted for fluxing purposes. The rock rings well under the hammer, but is easily broken, the fracture being clean and of flattish conchoidal form.

No trace of cleavage occurs, although the rock is strongly folded. On the other hand, the planes of bedding are splendidly preserved, and under the microscope no signs of strain or distortion can be discovered in the rock.

The characteristic weathering of the limestones is in spheroidal masses from 3 inches to 15 inches in diameter. These scattered boulders lie loosely on the surface, and without any visible connection with the masses below. In colour they are grey to bluish-grey, but on fresh fracture are black to bluish-black.

At the Mallee Tank mining operations revealed the presence of a highly calcitic blue and grey limestone, whose fossiliferous character had been almost obliterated by the alteration to calcite. The percentage of carbonate of lime in this occurrence is not high. The mine workings were not accessible during the present survey, but doubtless this Mallee Tank limestone is well-bedded as are all the masses of limestone of the same age along the same line to the south.

Both the limestone from the Rookery and that from the Mallee Tank are used as fluxes by the Queen Bee smelters. Partial analyses of the Rookery and Mallee Tank limestones made at the Department Laboratory are here supplied :—

No. 07–7430.—*Rookery Limestone.**

Calcium carbonate	99·03
Gangue	·53
Ferric oxide and alumina...	·14
Magnesium carbonate and undetermined	·31
	100·01

947–8.—*Limestone from Mallee Tank.*

947.—Rock 8146.

948.—Rock 8180.

	947.	948.
Calcium carbonate	84·80	81·51
Gangue	13·02	6·27
Ferric oxide and alumina	1·34	1·07
Magnesium carbonate, moisture, and undetermined ...	0·84	...
Magnesium carbonate	...	11·01
Moisture and undetermined	...	0·14
	100·00	100·00

Age and Correlation.—Fossils are fairly common in the Rookery limestone, and they are described as of Silurian age by Mr. W. S. Dun.

Organic remains were first found at the Rookery in 1887 by the Rev. Milne Curran,† and at a later date by Mr. William Anderson,‡ geological surveyor.

In 1910 the Writer and Mr. L. V. d'Apice obtained a representative collection of this limestone fauna.

Mr. R. Etheridge examined the collections of the Rev. Curran and Mr. Anderson, while Mr. W. S. Dun examined the 1910 collections.

Attached are the notes of Messrs. Etheridge and Dun :—

"The hand specimens forwarded by the Rev. J. Milne Curran, from between Rookery Station and Mount Narri Narri, half-way between Cobar and Nymagee, and those subsequently collected by Mr. Geological-Surveyor W. Anderson at the same locality, consist of a dark grey-blue fossiliferous limestone, with a more or less conchoidal fracture. The organic remains, of which it is so largely composed, indicate an Upper Silurian age, and a position probably near the Wenlock Limestone, if not absolutely representing that horizon.

. . . . . . A considerable portion of the limestone . . . seems to be composed of bivalved crustaceans, belonging to the Ostracoda, probably several species, but certainly amongst them is a *Beyrichia.* Fragments of Trilobites are also present, but too much broken up to be determinable. There are portions of Polyzoa, chiefly *Fenestella*; and one coral, a *Heliolites*, but only a fragment. But the indicative information is to be gathered from the mollusca. There is a Chonetes, allied to *Chonetes striatella*, Dalman, but possessing more upwardly-directed spines along the hinge margin. The genus *Spirifera* is well represented by a small form strongly resembling the characteristic Wenlock shell, *S. plicatella.* This species passes through many varieties, two of which are certainly represented here. There is the simple condition of the shell with striæ only and no ribs, known under the varietal name of

* Another sample analysed in 1912 gave a return of 98·68 $CaCO_3$. † Curran, J. Milne, "Carboniferous and Silurian Fossils, from Central N. S. Wales," Procs. Linn. Society, N. S. Wales, 1888–1889, p. 800. ‡ Anderson, William, Ann. Rept. Dept. Mines, 1887.

lineata; and there is one with broad, rounded costæ, answering to the variety *interlineata*, Sby. The second species of Spirifera I am at present unable to distinguish from *S. crispa*, Linn., and it is the most prevalent shell.

"The most important species is a small Strophomena, corresponding, in all but size, with the peculiar and characteristic *Strophomena corrugatella*, Davidson. The surface is longitudinally traversed by strong, narrow, thread-like riblets, the interspaces bearing concentric, irregular festoon-like wrinkles, giving to the shell a not easily forgotten appearance.

" . . . There is a single example of a shell having all the appearance of *Atrypa reticularis*, Linn., a fragment of which I believe to be a *Pentamerus,* after the type *P. galeatus*, Dalman, and a *Rhynchonella*. The latter is of equal importance with the Strophomena, as it possesses all the characters of *Rhynchonella Wilsoni*, Sby., especially the five regular ribs and the bold truncated and square front. . . . "*

The Silurian fossils collected by Mr. Andrews are found mainly in the Mallee Tank Beds in the vicinity of Rookery Station, from most probably some of the localities collected from by Messrs. Anderson and Milne Curran, and just referred to.

(*a*) From near Fireclay Pit, 2 miles south of Rookery Station, on the Restdown Mines road—

Lithistid sponge	*Spirifera*, cf. *crispa*
Favosites, cf. *gothlandica*	*Orthoceras*, cf. *ibex*
Stromatoporoid	Ostracoda
Atrypa	

(*b*) Near gate on Restdown Mines road, near Rookery Station, 22 miles south-east of Cobar—

Favosites, cf. *gothlandica*	*Spirifera*, cf. *crispa*
Favosites (dendroid)	*Spirifera*, cf. *nuda*
Stromatoporoid	*Rhynchonella*, cf. *angularis*
Crinoid remains	*Athyris* (?)
Strophomena, cf. *filosa*	*Orthoceras*
Orthis, cf. *striatula*	Ostracoda
Spirifera, cf. *Urii*	

(*c*) Near Rookery Station—

Stromatoporoid	*Heliolites*, cf. *porosa*
Favosites	*Heliolites* (fine-tubed)

(*d*) Limekilns, 20 miles from Cobar, on Nymagee-road—

Stromatoporoid	*Favosites*
Tryplasma	*Alveolites*

(*e*) From M.L. 1, near Rookery Station, Parish Bee, County Robinson—

Stromatopora	Monticuliporoid
Favosites gothlandica	Crinoid stems
Favosites (dendroid)	Brachiopoda, index

This fauna does not admit of close correlation with that of the more coastal Silurian deposits to the east, but there can be no doubt as to their Silurian age.

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* R. Etheridge, Ann. Rept. Dept. Mines, 1887, pp. 166-167.

A comparison of these rocks with the limestones of the Restdown area, a few miles to the south-west, may here be instituted.

Associated also with the Rookery limestones are quartzites, fireclays, fragmental rocks, conglomerates, and sandstones. The quartzite masses occur as low rises, which may be followed for 10 or 12 miles along the same course as the limestones. The limestones are patchy in their distribution, so also are the yellowish and irregular masses of quartzite.

In addition to this, large patches of yellowish-brown angular and subangular fragments of sandstone, with pebbles and subangular fragments of white quartz, occur, arranged along the same line. The limestone is inclined at a sharp angle, as are also the more western conglomerates, but no dips have been observed either in the quartzite or in the sandstone and quartz masses. The quartzite occurs as patches in ridges from 2 to 20 chains in length, and from 2 to 10 chains in width. Boulders of fossiliferous limestone at times are scattered over the quartzite surface. An excavation has been made in one of the Rookery paddocks for fireclay, and in the section thus revealed, the quartzite is seen to overlie the white fireclay, the plane of separation being horizontal and quite distinct. It is thus difficult to define the relations in age of the quartzite and limestones.

In hand specimens the quartzite possesses a subcherty or flinty appearance, with a subconchoidal to conchoidal fracture, breaking clean across the constituent grains of sand. The colour upon fresh fracture is a flinty grey, varying from light to dark. A white border of weathering is pronounced. In this weathered portion fragments of subangular quartz occur, as much as a third of an inch in length. The average size of the quartz grains is, however, less than one-hundredth of an inch in diameter. The quartz grains are quite glassy, but under the lens the weathered portions show a finely saccharoidal appearance.

Large patches of angular, subangular, and rounded fragments of quartzite and quartz appear to take the place of the quartzite just described at certain spots. The weathered portion is several feet in thickness, and forms slight ridges. The colour is brown and light yellowish-brown. The general appearance is that of a tuff or breccia in which pebbles occur frequently. The angular and subangular fragments are of quartzite, while the pebbles are of opaque white quartz. The pebbles, which are sometimes 3 inches in length, have a fresh look, and exhibit no sign of crushing, although the associated conglomerates are heavily crushed. No pebbles at all similar to those under consideration occur in the massive quartzite conglomerates in the vicinity. On the other hand, the material of which the pebbles are composed is highly suggestive of some of the gold quartz of the Cobar district.

In the present state of our knowledge of the Cobar rocks, it would be advisable to refer these quartzites and siliceous breccia-like masses to a fairly more recent redistribution of Mallee Tank rock material.

The Conglomerates.—The conglomerates of the Mallee Tank and Conqueror Mine only will be discussed here. The magnificent crushed examples to the immediate west will be described later.

Mining operations in the vicinity of the Mallee Tank and Conqueror Mines reveal the existence of sandstones, quartzitic sandstones, claystones, shales, and conglomerates. The dips are high, varying from 70 degrees easterly to vertical. The conglomerates are formed of well-rounded pebbles cemented with sandy material. Most of the pebbles are quite soft at present, and show beautiful red, yellow, and brown bands, and concentric shells of

Photo. Govt. Printer.

Distorted Quartzite Pebbles from Mount Drysdale, 25 miles North of Cobar.

One-third Natural Size.

Plate XIII.

Photo. Govt. Printer.

Elongated Quartzite Pebbles, Mount Drysdale, 25 miles North of Cobar.
About One-half Natural Length.

weathering. In a few instances the pebbles are of quartzite. Crushing phenomena are exhibited by the pebbles, sheared structures being common. The pebbles have very smooth surfaces, and appear to have been very hard at the time they were formed. The material of which they are formed consists of fine-grained sandstone, containing very small spangles of mica. It is probable that the associated quartzitic pebbles are of types which the rotten examples most closely resembled.

Age of Conglomerates.—The age of the Mallee Tank conglomerates may be referred to the Silurian, as they appear to belong to the same period of sedimentation as the Rookery and Mallee Tank limestones of Silurian age.

The Cobar Series.

General Character and Distribution.

This is a highly important group of schistose rocks of altered conglomerates, sandstones, and slates. In the majority of instances the sediments evidence heavy crushing, with a strong development of cleavage phenomena. The sandstones show a development of augen structures, while the bedding planes of the sandstones, the slates, and the conglomerates, are only discerned with difficulty, except in the larger mining excavations. In this report the sediments under consideration are considered to be of Silurian age, because of the occurrence of similar sediments interbedded with the Rookery limestones of Silurian age. It may be found hereafter, when the geological survey of Cobar, Canbelego, and Nymagee is complete, that the Cobar Series are merely a mass of Silurian sediments which have been altered locally along the strike of the contained gold and copper lodes.

Mr. J. E. Carne examined these rocks, and came to the conclusion that they were pre-Devonian in age. An extract from his report is here reproduced:—

> "The physical features of Cobar may be briefly described as a monotonous stretch of level country, above which a few hills and ridges of low elevation rise conspicuously. . . . . The country consists of sandstones and slates of probably Silurian age. On the Geological Map of the State, the elevated peaks have hitherto been coloured as Devonian, but, from the Writer's observations, and the identification of Silurian fossils by the Palæontologist, Mr. W. S. Dun, in similar rocks at Bobadah, and also in the limestone between Cobar and Nymagee, as well as the extreme lithological contrast between the highly cleaved and folded rocks, and the outliers of approximately horizontally-bedded sandstones and conglomerates—noted particularly between Mount Hope and Euabalong, and at Mount Boppy—it is more than probable that the Cobar rocks are older than Devonian."*

At the present stage of the inquiry into the geological ages of the Cobar sediments, we do not appear to have made any real advance beyond this conclusion reached by Mr. Carne.

Distribution.—These sediments have a great distribution in a meridional direction. Conglomerates distorted almost beyond recognition occur at Mount Dijou, approximately 50 miles north of Cobar, while similar rocks occur at Drysdale, 24 miles north, and at Restdown, about 40 miles south-east of Cobar.

* "Copper-mining Industry," 1908, p. 231.

It may be that the extremely altered conglomerates just mentioned are older than the Cobar Series. Nevertheless, they are on the same line and their associated sediments are almost identical with the sandstones and slates of the Cobar Series.

Detailed Descriptions.

The Conglomerates and the Sandstones.—These two classes of rock are here treated together, inasmuch as they are intimately associated, the sandstone frequently forming a matrix for the conglomerate pebbles. The conglomerates frequently attain enormous thicknesses, but may merge into sandstones at many points along the strike. Sometimes the conglomerate pebbles retain their original ellipsoidal form; at other times, as at Mount Drysdale, they are drawn out into double-ended cigar or into discoidal forms; or, as in the Queen Bee district, they have been intensely faulted. (Plates 12–15.) The sandstone grains may take on "eye" structures, as at the Bee and Nurri Mountains, at Fort Bourke Hill, and near the Tharsis Mine. It will be advisable to discuss here the conglomerates of the Rookery, of Restdown, of the Nymagee Road from the 43rd to the 36th mile-peg, and of Mount Drysdale, also the sandstones of Mount Drysdale, the Tharsis locality, Fort Bourke, The Peak, the Bee and Nurri Mountains.

(1.) *Dijou Conglomerates.*—These outcrop as bold hills from the 37-mile peg along the Cobar–Bourke Road for a considerable distance to the north. The metamorphism has been extreme, resulting in the squeezing of individual pebbles into discoidal and pointed elliptical forms. Where the pebbles are most crowded together, there the metamorphism has been most pronounced. The beds have a great thickness, and the dip is almost vertical.

(2.) *Mount Drysdale Conglomerates.*—The conglomerates included under this title stretch from Mount Drysdale southward through Moquilamba. The pebble beds may be thin or thick; the strike is almost north-east and south-west, and the dip is approximately vertical. A bed may be almost wholly composed of pebbles, or it may consist of sandstone with sparingly distributed pebbles. A curious observation may be here recorded. Wherever a bed of conglomerate consists almost entirely of pebbles, there the individual pebbles, although of the toughest quartzite, have been drawn and teased out into the most fanciful patterns. (Plates 12 and 15.) Some are of the forms of sausages, some of long spindles, some of elongated discs, others exhibit elongated angular forms, triangular or rhomboidal in cross-section. The ends of the distorted individuals evidence still greater action, because whereas the bulk of the distorted pebble lies, so to speak, in one plane, the ends are bent out of that general plane. Where pebbles are infrequent in a bed, there distortion is almost negligible. In still other beds distortion of certain pebbles, but not of others, is marked. Strong joint planes cross the conglomerates, the individual pebbles being cut through as sharply as with a razor by the horizontal joints.

Plates 12 and 13 illustrate the distortion to which the pebbles have been subjected. The pebbles are extremely resistant to the forces of erosion by reason of their quartzitic nature, and they lie scattered plentifully upon the hillsides, looking as fresh as if only just detached from their settings. The colour of these weathered individuals is a prevailingly light greenish-grey, varied with brown and red patches and streaks. On the weathered faces the peculiar strains and distortions to which the rocks have been subjected are shown remarkably well.

Plate XIV.

Photo. Govt. Printer.

Sheared Quarztite Pebbles, Bee Mountain, 12 miles South-east of Cobar.

One-half (diameter) Natural Size.

No. 1.

No. 2.

No. 3.

No. 4.

Photo. Govt. Printer.

Nos. 1 and 4. Elongated Pebbles from Mount Drysdale.
Nos. 2 and 3. Sheared Pebbles, 10 miles South-east of Cobar.

About One-half Natural Length.

The material of which the pebbles are composed is characteristically a fine-grained quartzite, in which the texture is only discernible with difficulty. The larger grains appear to have been well rounded.

The matrix of the pebbles varies from a dense greenish sandstone to a tough sandy slate. The sandstone grains may assume "eye" structures, as at the Bee and Nurri Mountains, at Fort Bourke Hill, and near the Tharsis Mine.

(3.) Along the old road to Nyngan, near the top of the rise, 2½ miles from Cobar, a great number of relatively small quartz and quartzitic pebbles may be seen. They are crushed and elongated, but not to nearly the same extent as the Drysdale examples. The pebbles have been well rounded, and the matrix is of argillaceeus sandstones and sandy slates. Similar pebbles associated with argillaceous sandstones, sandy slates, and quartzitic sandstones (with traces of fossils) occur to the east of the Cobar rifle-butts.

(4.) *Queen Bee Mountain and Nymagee Road Conglomerates.*—Like the Drysdale and Moquilamba outcrops, the conglomerates under consideration have an extremely large development. They stretch from the 42-mile to the 34-mile pegs, along the old Nymagee road, and in the widest portion they extend from the Mallee Tank and Conqueror Mines to the northern end of the Queen Bee Mountain, a distance of between 2 and 3 miles. This great width is probably owing to a local decrease in the dip values of the Palæozoic sediments. The Nymagee road conglomerates are in the form of a huge lens, which in turn consists of a number of minor lenses, set in a matrix of sandstone and slaty sandstones. The rapidity with which the conglomerates appear and disappear along the line of strike is astonishing. Very few outcrops occur, but the ground is frequently strewn with isolated pebbles from the conglomerate, the quartzite of which they are composed being much more resistant to the forces of weathering than the dense sandstone matrix. On the Bee Mountain the pebbles are to be seen in abundance in places, lying loosely upon dense greenish-grey sandstones which contain not more than 5 per cent. of quartzite pebbles.

The metamorphism to which the pebbles have to be subjected has been most capricious in its action. Frequently the pebbles show no evidence of distortion. Especially is this the case where the pebbles are scattered through solid sandstone. On the other hand, in places where the pebbles are crowded together, as to the north of the Bee Mountain, they show wonderful distortions. But even at these places the great bulk of the conglomerate has escaped alteration; the intense action appearing to be confined to zones, and not extending over the whole area. The characteristic type of distortion in the area under consideration differs from that of Mount Drysdale and Moquilamba, although the individual pebbles are almost identical in mineral composition. At Drysdale the pebbles have suffered elongation, while along the Nymagee road they have been repeatedly sheared in a direction at right angles to the longest axes of the pebbles. Figs. 2 and 3, Plate 15, illustrates this shearing action well. These movements may affect a pebble equally throughout, causing the pebble to be faulted symmetrically; usually, however, one side or end of a pebble is not faulted at all, while the other side or end has been decidedly displaced. In such cases the fault or shearing action may be seen to die out and pass into a continuous curved surface. A common effect of such action is the production of several parallel shear planes with the formation of many smaller shear zones in the intermediate zones. (Plates 14 and 15.) The traces of these small or incipient shearings are preserved as slight parallel corrugations on the pebble surfaces. In many cases, even in the Bee conglomerates, pebbles show elongation and crushing at the same time. The effect of this is to produce most peculiar and interesting structures. (Plate 15, Figs. 2 and 3.) Frequently pebbles have been rendered flattish and elliptical in plan, with a central axial depression, somewhat like in an ingot of overpoled copper. In such cases a multitude of short projections like small valves or the points on a coarse steel file are arranged symmetrically along the pebble surface. Pebbles of this type may be seen to be crossed by multitudes of fault places. Frequently the ends of the pebbles are nipped off and flattened so as to appear somewhat as glaciated pebbles. (Plates 12 and 14.)

The pebbles vary in size from ellipsoids, 1 inch in length, to boulders 2 feet in length. The bulk of the specimens examined were from 4 to 9 inches in length.

Quartzite is the material of which the pebbles are composed. Generally it is of exceedingly fine texture being with difficulty resolved by a pocket lens, and the surfaces of the individuals are quite smooth, excepting those which have been crushed. Coarse quartzite grains are uncommon. The quartzite appears to have been derived from old quartzite and quartz schists and not directly from granitic quartz.

The accompanying descriptions of two of these quartzite pebbles have been supplied by Mr. G. W. Card :—

> "**8182.** 10 miles south-east of Cobar. The specimen is too compact to admit of examination under a lens. A microscopic examination was made of a thin section prepared from the unsheared portion of the pebble. The larger grains are well rounded ; the smaller ones are irregular and interlocking. There is practically no indication of strain."
>
> "**8122.** M.L. 9, parish Narri." Quartzite, buff-coloured, the constituent particles ranging up to 4 mm. in diameter.

Under the microscope, well rounded quartz pebbles are seen lying in a groundmass of much smaller interlocking grains. Here and there a grain of felsite is seen. Locally there are indications of strain, and here and there a grain has been shattered.

In the light of the great stress to which these conglomerate pebbles have been subjected, it may appear strange that so little sign of strain under microscopic examination is evident. It is doubtless to be accounted for by the readjustment of strains in part through recrystallisation.

Mount Nurri.—The conglomerates here are only represented by infrequent pebbles, which are not so distorted as those which are closely crowded together. The enveloping sandstone grains evidence more strain than those of the sandstones further north.

The Rookery Conglomerates.—These lie outside the area included in the present geological survey, but they represent folded members of the great series of conglomerates under discussion, and are here included because of the apparent intensity of alteration which is indicated as the beds are followed eastwards and southwards.

Two outcrops were seen in the Rookery area, the better example occurring about 5 miles south-east of the Rookery Head Station. The outcrop was about 400 yards in width, the strike was almost north and south, but the dip was not observed. The pebbles were closely crowded together, and they were wonderfully distorted. Unlike the Nymagee-road and Queen Bee examples, every pebble and boulder was much elongated and flattened, the longer axes being arranged almost vertically.

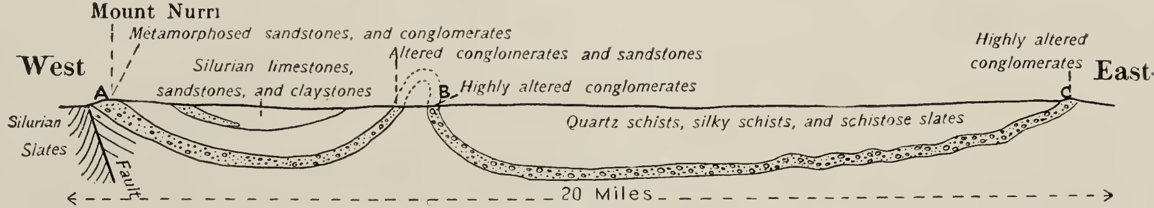

Fig. 1. Sketch Section across Restdown and Rookery Beds.

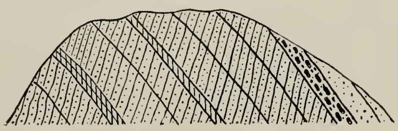

Fig. 2. Detail of Structure at A in Fig. 1.

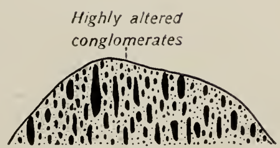

Fig. 3. Detail of Structure at B.

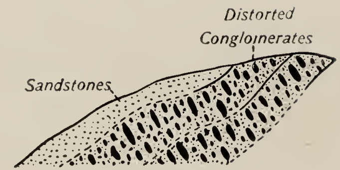

Fig. 4. Structure at C.

Note the elongation of pebbles almost at right angles to planes of bedding.

Individual pebbles and boulders are not so resistant as in the case of the Queen Bee conglomerates, the Rookery and Drysdale pebbles being almost identical, and appearing to consist of a hardened sandstone or clay, rather than of a quartzite. In the case of the dense quartzites faulting and shearing action is predominant, in the case of the Rookery and Drysdale pebbles elongation is the characteristic alteration. In other words, the quartzite appears to be rather brittle while the indurated argillaceous rocks appear to be much more plastic under stress.

The Restdown Conglomerates.—This occurrence is one of the finest in the area. The associated sediments are quartz schists, schistose sandstone, silky schists, and allied rock types. Elongation of the pebbles is common, but bands of quartzite pebbles are not so decidedly distorted as are those of more argillaceous types. A peculiarity is the lack of sympathy between the arrangement of the bedding planes and the planes along which the maximum elongation of pebbles has taken place. This is shown in Plate 16, Figs. 3 and 4. An ideal section across these southern conglomerates is supplied in Plate 16.

The Sandstones.—Intimately associated with the conglomerates are the sandstones of the Cobar Series, indeed the sandstone is the common matrix of the quartzitic pebbles, and the two replace each other with astonishing rapidity along the line of strike, the conglomerate generally tapering out as lenses into the enveloping sandstone. Typically the sandstones are developed west of the conglomerates, the main mass of the slates lying to the west of these again.

The sandstones are well developed at Mount Drysdale, and to the south of the township of Cobar. The outcrop at Mount Drysdale is very imposing, but thence to the Tharsis Mine, $1\frac{1}{2}$ miles north-east of Cobar, traces only of the sandstone are to be found. From the Tharsis to the south end of Mount Nurri, a distance of 23 miles, the sandstone may be easily traced by the residuals of Fort Bourke, the Occidental, The Peak, the Bee, and Nurri Mountains. The thickness of the sandstone is very variable, as it is frequently replaced by slates. A series of strike faults in the sandstone is strongly suggested by the general map, the lines of sandstone strike and of faults not showing much divergence, especially from the Young Australian to the Chesney Mine, where the strikes of both dislocations and sandstone are almost identical. At the Bee Mountain and Mount Nurri, on the other hand, the strikes of the strata and the dislocations vary as much as 30 degrees, and the planes of bedding and of dislocation are inclined to each other. It has been found impossible to even approximate to the thickness of the sandstones and the conglomerates because of the lack of natural sections and the influence of this heavy faulting action.

Mount Drysdale.—The sandstones of this locality possess dips almost vertical. In colour they are grey to greenish-grey. A slightly schistose appearance is observable at times, the sand grains being then arranged parallel to the planes of dislocation.

The varying character of the beds is shown by the weathering action, certain beds having been removed in the formation of gullies by streams, while others form high steep ridges and walls to these valleys of erosion.

Tharsis Mine.—The sandstone occurs a few chains to the east of the mine of this name. It here forms insignificant exposures of a light yellowish-brown colour. In hard specimens it appears to be an argillaceous variety of sandstone in which the sand grains have had a definite arrangement imposed upon them. It was the peculiar "eye" structures exhibited by the sandstone outcrops near the Tharsis that induced the Writer to attempt the mapping of the Cobar Series in the typical absence of rock exposures. Not all the sandstones exhibit this " eye " structure—in some it is obscure, while in many it is lacking altogether. It occurs characteristically in zones, and in this respect it resembles the crushed conglomerates. In proportion as the " eye " structure is developed so does the rock depart in character from a freestone. A rude fissility then characterises it, and it becomes almost impossible to prepare a cube of the rock with the geological hammer, the tendency being to break off parallel to the planes of incipient schistosity. The sand grains are subordinate in amount to the felspathic cementing.

Fort Bourke and Chesney.—The eastern portions of these hills are composed of the siliceous lodes and of slates, which are reddish in colour above water-level. At the northern end of the residual the sandstones are cut off abruptly against the lodes, the western side being composed of red slate, but along the southern portion the strikes of both sandstone and lodes are almost coincident. The sediments, however, dip strongly against the inclination of the lodes. The bedding planes have been almost obliterated in places, both by reason of a later pseudo-cleavage of joint developments, and by the compression and alteration along these old planes of parting. The cleavage and powerful jointing is mainly in planes parallel to that of the lodes, whereas the bedding planes are much contorted. Silicification of the sandstones is pronounced, the silica having entered along a great number of fissures, and having thence partly replaced the country. All the evidence points to the silicification having taken place under great load. The quartz has frequently replaced the country in lenses arranged in parallel lines (Fig. 17, of Fort Bourke ore), or the lenses have been arranged such that their shorter axes are collinear, and coincident with an incipient fault (p. 57). This type of silicification is characteristic of the field, both in the Silurian and the Devonian rocks.

Fig. 16 is a sketch section across the Chesney and Fort Bourke fractures.

The sandstones are argillaceous, passing at times into slaty sandstones and sandy slate. They have been altered to quartzites in places where not far removed from the lode. The bedding planes are fairly well preserved in the less massive types.

Occidental Sandstones.—Rocks from this locality possess the same general characteristics as those of the Mount Pleasant, Chesney, and Fort Bourke types. They dip strongly against the Occidental lode and do not reapppear on its western side. About 30 chains to the east of the Occidental open cut, sandy slates with well-preserved bedding planes take the place of the sandstone. Further east again traces only of sandstone and pebbles occur. Cleavage of the sandstones and development of "eye" structures occur in the Occidental group, and the bedding planes are in places much less conspicuous than those of the cleavage and jointing. Following the strike of the Occidental lode southwards across the company's dam, the sandstones are observed to swing more to the north-east and to end then suddenly against the western foot of the Peak. The peculiar arrangement of the cleavage and the cross jointing in the sandstones, both here and in the sandstones of the Cobar Series generally, is most instructive. The strike is always definitely crossed by the cleavage, the jointing causing the outcrop to consist of so many plates arranged across the line of strike. The relation of strike to cleavage of sandstones is well shown on a small rise midway between the Occidental Mine and the Peak.

This is only one of numerous examples illustrating the great development of cleavage in the sandstones and the slates of the Cobar Series. Other examples will be supplied when describing the Peak sandstones and the Cobar slates.

The Peak Sandstones.—Two belts of sandstone occur on this residual, one of which approaches from the west and ends abruptly against a dislocation running along the western foot of the hill, and another which forms the central portion of the hill and has an almost meridional strike. The eastern one ends in a slight rise, elevated about 2 feet above the associated green and grey slates. The peculiar jointing which this rock has suffered, and the partial obliteration of the bedding planes cause difficulty at times in ascertaining the dip of the beds. Indeed it is not too much to say that one unaccustomed to altered rocks would certainly record the dips wrongly, and mistake the structural planes which are parallel to the lodes for the bedding planes.

As in the more northern sandstones the Peak rocks show much silification and a development of " eye " structures. With the sandstones are associated many rock types of finer texture and of a slaty nature. (Fig. 2.)

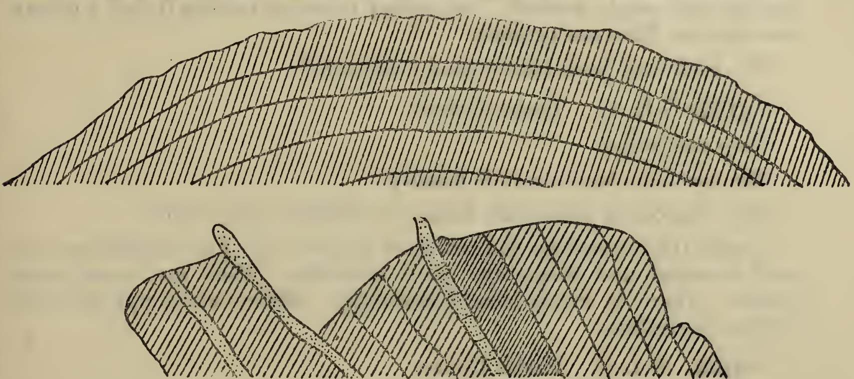

Fig. 2.

Sketch sections of details of structure in sandstones and slates of The Peak, illustrating bedding and cleavage planes.

Between the northern and southern portions of the hill there is a striking dissimilarity in the sandstones. The variations in rock character are also suggested by the topography. The southern portion of the Peak, or " The Peak " proper, presents a conical aspect, while the northern portion runs as a long, low, hard ridge ending suddenly against The Peak. The rock to the south is mainly a bluish-green sandstone, exceedingly tough and hard, and ringing under the hammer, while the northern and continuous ridge is of grey, buff, and yellowish-brown argillaceous sandstones. (Fig. 3.)

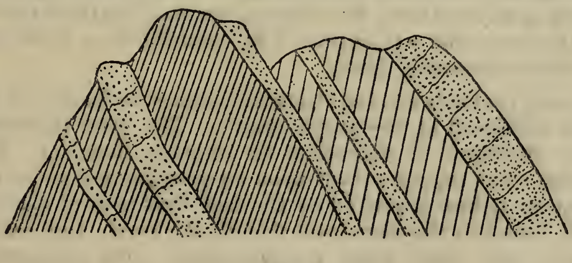

Fig. 3.

Sketch section illustrating cleavage and dip in Peak sandstones and slates. Note the change of cleavage plane dip when passing from slates to sandstones.

There are two ways to account for the collinearity of these types—

(*a*) To assume that the Blue Lode, the Premier Lodes, and their northern continuation mark a line of fault, this being the line which separates the grey and blue types of sandstone.

(*b*) To account for the variability by assuming a variable content of secondary silica.

The accompanying petrographical descriptions have been supplied by Mr. G. W. Card :—

"**8191.** Cobar Peak Mine; depth 150 feet. A soft pyritous, grey, non-fissile rock.

Under the microscope, there is much quartz, which is under strain, and is also much washed. Secondary minerals (zoisite ?), and a colourless acicular form are present.

The rock may have been a sandy clayslate."

"**8192.** G.L. 42. Parish Cobar.

Grey sandstone.

The specimen shows a rude fissility.

The component grains are barely resolvable under a lens.

Under the microscope the structure is obscure. The particles are not well rounded, and many are quite irregular. They are under some strain. There is much cloudy interstitial matter, which appears to be crypto-crystalline."

"**8193.** M.L. 5. Parish Cobar.

A non-fissile pink rock, with a gritty feel. Its clastic character is just discernible under a lens.

Under the microscope, the general appearance suggests a possibility of tuffaceous origin. There are numerous fragments of quartz with a fine micaceous material. The particles are quite irregular in form, and show some strain effects."

Queen Bee and Nurri Mountains.

These residuals are composed, in the main, of what appear to be argillaceous sandstones with a slight schistose structure. They represent the maximum width of the sandstones observed in the Cobar area. Numerous dips have been observed, their average value being 50 to 55 degrees, and the direction being always either a few degrees north or south of east. Dips were obtained in this area, and a thickness of at least 2,000 or 3,000 feet must be assumed for these interesting beds.

The first thing that attracts the attention is the rude fissility of the rock and eye structures exhibited by the quartz grains. The eyes themselves appear to be thinly sheathed in micaceous or steatitic material. The idea of crushed igneous rocks suggests itself upon an examination under the lens, but their sedimentary nature is proved by the fact that beds of quartzite pebbles are frequently found in the mass, and that to the north and east of the Bee Mountain they pass into dense conglomerates. As compared with the northern occurrences—for example, the Chesney, Fort Bourke and Tharsis exposures—they are very massive.

In colour the rocks are grey, greenish-white, pinkish, and brown.

PLATE XVII.

Photo. G. W. Card.

Fig. 1. Schistose Sandstone, Queen Bee Mine.
Crossed Nicols, 1 inch mag.

Photo. G. W. Card.

Fig. 2. Quartz Crystal Stretched and under Optical Strain, Bee Mountain Gap.
Crossed Nicols, 1 inch mag.

The following notes on the petrography of these rocks have been supplied by Mr. G. W. Card :—

"**8106.** Near Queen Bee Trigonometrical Station.

A rudely schistose sandy rock, creamy in colour. Quartz particles readily detected without lens.

Under the microscope, the clastic character is evident. There is much less quartz than the megascopic inspection suggests, the proportion probably not reaching one-tenth. The quartz particles are very angular, and lie quite without orientation. Here and there strange shadows are seen, and one rutilated grain was detected. The rest of the rock is obscure, but seems to be made up in part of fragments, in part of matrix, both of which are replaced by fine mica. A sandstone grain was noticed.

The rock may, perhaps, be an altered tuff."

"**8113.** Mount Nurri.

A greenish-grey soft, rudely fissile rock.

Under the microscope the fissility is seen to be due to incipient crushing. Much quartz is present; it is under strain, and shows a tendency to assume an "eye structure," due to crushing. Some zoisite is present.

The original nature of the rock is doubtful, but it may have been a sandy clayslate."

"**8159.** Queen Bee Mines.

Schistose sandstone.

A reddish rock, the constituents of which are readily recognisable with a lens.

Microscope examination is difficult, as thin sections are not available. The effects of crushing are marked. The particles are flattened to more or less lenticular forms and overlap one another. All are under strain, and are sheathed in a stringy yellow material (mica?). They lie in a general crypto-crystalline groundmass. The rock is not mashed; here and there are grains that are entirely unaffected, and stand out conspicuously because of their roundness."

Plate 17. Fig. 1 illustrates the character of the rock.

"**8163.** Queen Bee Mine.

A sheared rock. Perhaps a pebbly clayslate."

Cobar Series.—The Slates.—The slates are intimately associated with the sandstones, but are typically developed to the west of the same. The three —conglomerates, sandstones, and slates—form a great series, occupying the centre of the field. A reference to the general map will show the peculiar relations in space of the main bulk of the sandstones and the slates. From the southern point of Mount Nurri to the extreme northern point of the extension of The Bee Mountain, the slate and sandstone junction appears to lie at the foot of the western hill slopes, and, moreover, such junction is suggestive of heavy dislocation. The evidence for this will be supplied in a later chapter. From the southern end of The Peak to the Blue Lode, and thence to the Tharsis by way of the Occidental, Chesney, and Fort Bourke lodes, the red slates are separated from the sandstones by the lines of lode themselves. Westward of this line the slates extend for a considerable distance, as much as a mile and a half in places. The slates are of very fine texture, and show magnificent cleavage phenomena, the planes of the latter being generally parallel to the associated lode planes. Natural sections are extremely rare, but here and there the strike may be seen in the more sandy varieties, the cross cleavage and the lines of iron staining indicating the strike. Only in mining excavations, however, can the bedding planes of the finely-textured slates be made out. Splendid examples of both bedding and cleavage planes are to be seen in the excavations made in the mullock tank of the Great Cobar Mine, at the north end of The Peak, and at the Tharsis Mine. The prevailing colour of the slates below water-level is a bluish-grey to bluish and greyish black. At the surface, the prevailing colours are red, yellow, chocolate, grey, and white. In this respect, the slates cannot be distinguished from the Weltie shales lying to the east. Both are excessively fine in texture; both have the same bright colours; but the one is highly cleaved and jointed, the other is not at all compacted, and can only with difficulty be preserved in hand specimens, because of its extreme tendency to break up along its planes of bedding. This cleavage, however, may be observed to die out east and west, as one moves away from the lodes and dislocations.

A description of the coarser types of clayslate lying about a mile to the west of the Great Cobar Lode may be taken as typical of one phase of the slates. The clayslates under consideration at times possess a sandy content. At the surface they present the appearance of very ferruginous and indurated slates, so ferruginous indeed that prospecting holes have been sunk on them, in the hope that they might have formed the cappings of lodes. Other members associated with them show superficial accumulations of lime and magnesia carbonates. Upon closer examination this induration and this lime, iron, and magnesia content is seen to be but superficial. A few feet below the surface the rock is often similar to a kaolin in general appearance, from which the iron, magnesia, manganese, and lime have been drawn to the surface in this sub-arid climate, and been deposited in the upper layers or portions upon evaporation of the uprising water. The iron commonly replaces the clayslates, the magnesite forms superficially as large nodules at the expense of the enclosing rock, the calcareous tufa is deposited along the joint planes, while the manganese dioxide is deposited as black layers and mammillæ along the joints. The bedding planes take up a great portion of the iron at this particular place, and they appear much darker than the material between these planes. Ochreous red, brown, and yellow tints characterise the partial iron replacements. As the bedding planes are closely set together; as the material deposited along such planes is more durable than the less altered slate itself; as the rock texture is fine; as the cleavage, moreover, is inclined at a decided angle to the bedding; and as the cleavage and bedding planes are both highly inclined, the variable weathering thus induced causes the outcrop to assume the appearance of miniature Alps, with their accompanying *arrêtes*, the bedding planes cause the prominences on the *arrêtes*, and the ochreous yellow and brown material cause the notches in the *arrêtes*.

The finely-textured slates of yellow, purple, chocolate, and red colour present no such aspect as the variety just described, but weather out as tiny laminæ, in which no structures other than the perfect cleavage and jointing of the field are visible. Some of these are more siliceous than others; others are more "blocky." Thus the slates forming the western country of the Great Cobar are more blocky than the harder and more siliceous types of the eastern country, in which the poor siliceous gossans occur.

The subjoined petrographical notes have been supplied by Mr. G. W. Card:—

[8085] Tharsis Mine, Cobar.

"Clayslate, approximating to phyllite. A soft, ruddy fissile (along cleavage planes) and slaty rock, whose bedding planes are indicated by bands of a darker colour.

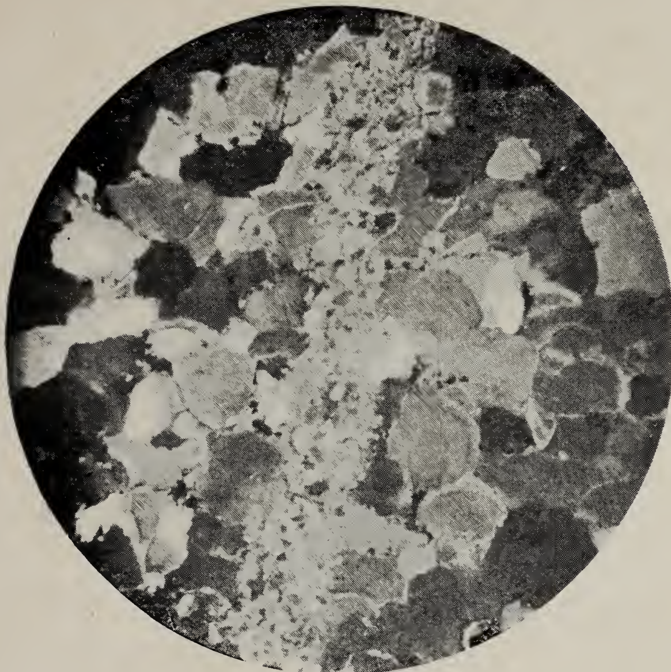

Photo. G. W. Card.

Fig. 1. Quartzite, $\frac{1}{2}$ mile North-west M.L. 14, Cobar.
1 inch mag.

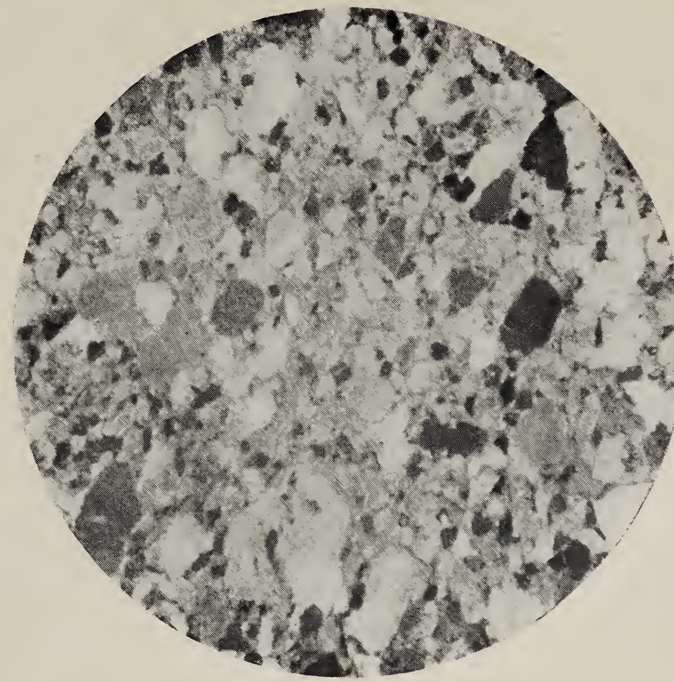

Photo. G. W. Card.

Fig. 2. Pebble from Sheared Conglomerate Quartzite, 10 miles South-east of Cobar.
1 inch mag.

Under the microscope the darker bands are seen to be more homogeneous in character, and freer from larger particles. The rock is quite Clastic, consisting of abundant small particles of quartz and other material, in a crypto-crystalline matrix. The matrix has a very fibrous appearance under high powers, and is probably, to a large extent, composed of mica."

The following analyses of slates were determined at the Departmental Laboratory :—

892–11.—Clayslate from the Open Cut, Great Cobar Mine.

Western side of Lode.

Moisture at 100° C.	1·02	
Water above 100° C.	3·09	
Silica	62·13	
Alumina	19·06	
Ferric oxide	5·00	
Ferrous oxide	1·53	
Manganous oxide	0·02	
Lime	0·74	
Magnesia...	1·70	
Sodium chloride*	0·31	
Soda	0·15	
Potash	4·43	
Titanium dioxide	0·72	
Phosphoric anhydride	0·15	
Sulphur trioxide	absent.	
Chromium sesquioxide	,,	
Strontia	present	Spectroscopic reaction only.
Lithia	,,	
Vanadium sesquioxide...	absent.	
	100·05	

* Soluble in water.

(Analysis by Mr. W. A. Greig.)

1396–11.—Clayslate, from east side of the Great Cobar Lode, Cobar.

Chemical Composition.

Water at 100° C.	0·74	
Water above 100° C.	3·12	
Silica (SiO_2)	63·06	
Alumina	19·42	
Ferric oxide	5·30	
Ferrous oxide	0·36	
Manganous oxide	trace.	
Lime	0·24	
Magnesia...	0·84	
Soda	0·44	
Potash	4·74	
Titanium dioxide	0·80	
Phosphoric anhydride	0·09	
Sulphur trioxide	trace under ·01 per cent.	
Nickel and cobalt oxides	absent.	
Barium oxide	0·08	
Strontium oxide...	present	Spectroscopic reaction.
Lithium oxide	,,	
Vanadium oxide	absent.	
Carbon dioxide	0·05	
Organic matter	0·85	
	100·13	

Gold and silver a few grains per ton ; copper a minute trace.

(Analysis by Mr. W. G. Stone.)

891-11.—Clayslate ("X 17") from near The Peak.

Moisture at 100° C.	0·33	
Water above 100° C.	3·10	
Silica	62·12	
Alumina	18·90	
Ferric oxide	1·75	
Ferrous oxide	4·41	
Manganous oxide	0·05	
Lime	0·78	
Magnesia	2·72	
Soda	0·29	
Potash	4·86	
Titanium dioxide	0·75	
Phosphoric anhydride	0·14	
Sulphur trioxide	absent.	
Chromium sesquioxide	,,	
Baryta	0·04	
Strontia	trace	Spectroscopic reaction only.
Lithia	,,	
Vanadium oxide	absent.	
	100·24	

A trace of soluble chlorides present.
(Analysis by Mr. W. G. Stone.)

Conditions of deposition of Cobar Series.

A great development of slates occurs both east and west of the sandstones at Cobar itself, but the main arrangement of the rocks shows the conglomerates to the east, the sandstones immediately to the west, and the slates adjoining these again on the west. The prevailing dip at Cobar is westerly at a high angle. At Mount Nurri and the Queen Bee Mountain the slates underlie the sandstones, and these in turn underlie the conglomerates, the prevailing dip there being easterly at an angle of 50 degrees. If now attention be directed to the material composing the various sediments it is at once evident that the conglomerates have been derived from exceedingly compact and tough quartzites; and it is also evident that the matrix of the conglomerates is a sandstone whose sand grains appear to be composed of material similar to that of the pebbles. In this connection it is interesting to note the presence of dense quartzites and quartz schists with argillaceous schists to the immediate east-north-east, east, and south-east of the Cobar district. Girilambone marks one of these exposures; Hermidale and Nymagee mark others.

The evidence of the rock succession of the Cobar Series then suggests the existence of high land to the east and north-east of Cobar with a shore-line extending from south of Restdown to north of Mount Dijou, and an epicontinental sea over the Cobar area. The thick masses of finely-textured slates at Cobar itself indicates the redistribution of material brought down to the sea by sluggish rivers, such sluggishness being possibly assisted by a decided movement of subsidence such is evidenced along the shore-line of Eastern Australia at the present day.

Age and Correlation.—The Cobar Series appears to represent a mass of deformed Silurian sediments. To the north-east, the east, and the south-east, as at Girilambone, Hermidale, and Nymagee, we have masses of schists and quartzite apparently of great age, and it is possible that the conglomerates, sandstones, and slates of the Cobar Series have been derived from this older land to the east by the agencies of denudation. In the production of these huge conglomerates there appears to have been both the action of a sea beating upon a rocky shore and the presence of swiftly-flowing rivers.

Certain points in the history of the sedimentation under consideration still require elucidation. The main body of the Cobar slates certainly lie west of the sandstones and the other more coarsely textured rock members, but the fact must not be forgotten that the Cobar sandstones appear to be faulted against the Cobar slates, and thus, in this waste-cloaked area, the true order of superposition of the beds can be only approximately indicated. Another point also may be mentioned, which introduces a much greater element of complexity into the case. Thus, if the cleavage and the partially schistose phenomena prevailing among the members of the Cobar Series had affected the fine-grained argillaceous sediments of the Cobar district equally, there would have been but little difficulty in ascertaining the main features of the relations between the highly-cleaved Cobar Series and the associated uncleaved sediments. But examinations conducted at Cobar itself suggest that the highly-cleaved Cobar sandstones and slates at times pass gradually into unaltered Amphitheatre (Devonian) clay stones and shales. Until the Geological survey of the Cobar district shall have been extended to Canbelego, Restdown, Nymagee, and Shuttleton, the most reasonable inference is that during the compressive movements which closed the Devonian Period in this area, enormous faulting action took place which brought some of the older rocks through the Devonian sediments.

The Amphitheatre Series.

General Character and Distribution.

The sediments described under this head consist of massive quartzites, sandstones, claystones, and shales. All of these rock types alternate frequently with each other. The shales and claystones form a much greater portion of the rock volume than that of the sandstones and quartzites. A portion only of the area occupied by this interesting group was examined in detail, but it was definitely ascertained that the rocks under consideration extend from a point 5 miles west of Cobar along the Wilcannia road to the 40-mile peg along the same track. Rocks, also apparently of the same age, commence within a mile of the township of Cobar along the Wilcannia road. These rocks at the $3\frac{3}{4}$-mile peg cross the Louth road and stretch indefinitely thence in both north and north-west directions. Gundabooka, 60 miles north of Cobar, also appears to belong to this group. The sandstone and quartzite ridges lying about 30 miles to the south-west of Cobar are Devonian. So also the masses of rocks stretching away to the west of a line passing just west of Cobar and Mount Hope are probably of Devonian age.

A great dome-shaped anticline occurs at the Amphitheatre Station 12 miles west-south-west of Cobar. The axis of the inner portion of the anticline is 6 miles in length, and its width is $1\frac{1}{2}$ miles. It plunges steeply to the east, but gently both to the west and south-west. At the 7, 8, and 9 mile pegs along the Wilcannia road the rock dips are almost vertical, and they slope away from the anticlinal dome. About 8 miles from Cobar along the Mossgiel road the sandstones and quartzites also dip away from the anticline. These sandy rocks (quartzites) are characterised by abundant encrinite and brachiopod remains, apparently of Upper Devonian age. Between the 7 and 6 mile pegs along the Wilcannia road no dips are observed. Between the 6 and 5 mile pegs a fossiliferous belt of quartzite may be seen possessing a dip towards the anticline. This dip, however, appeared to be merely local. (Main map.) Thence to the 2-mile peg no dips were observed. At the Alley Trigonometrical Station, 2 miles west of Cobar, a set of dips were observed varying from 65 to 85 degrees in amount, and in a direction away from the anticline, that is to say, against the observed dips of the C.S.A. Beds, 1 mile farther to the east. The dips of the Water Tower Beds at the 1-mile peg along the Wilcannia road are obscured, but they appear to be almost vertical. This is suggestive of heavy faulting in the locality, and it is possible that the apparent thickness of the Amphitheatre Series is due in great measure to faulting and folding.

Subjoined are short descriptions of the principal rock belts in the great Amphitheatre Series, the order of description observed being as from east to west.

The C.S.A. Beds.

There are considerable lithological differences existing between the rock types of this stage and those of the western members of the Amphitheatre Series. For example, cleavage is commonly developed in the C.S.A. sediments, but not in those to the west. It is not, however, a constant feature, even in these eastern beds, and is absent except in the neighbourhood of the lodes. On the other hand, quartzites, sandstones, and claystones, almost indistinguishable from those of the Amphitheatre Series proper, form the western portion of the C.S.A. sediments, and it appears advisable to class the two rock groups together.

General Character and Distribution.—Quartzites, sandstones, cherty and ferruginous claystones and slates are characteristic, and they run fairly parallel to the associated quartzites and sandstones to the west for a distance of almost 20 miles. Near the township of Cobar itself the beds seem to be much crumpled and pinched, and their dips all along the outcrops, when observed, are opposed to those of the western sediments. This is suggestive of heavy faulting.

The beds are peculiar, in that the northern members are not cleaved and jointed to nearly the same extent as the more southern exposures immediately to the west of Cobar.

Yellow and peculiarly-jointed cherty claystones outcrop weakly about 2 miles south of Parish Cobar; thence for several miles northwards they are quite hidden by the prevailing waste sheet. They reappear on the rise to the south of the Great Cobar Dam, the easternmost member outcropping in the old "open cut." Thence the western members sweep through the hospital grounds, beyond that northwards to the immediate east of the "Water Tower" belt, and thence to the C.S.A. blocks by way of the 3-mile peg on the south road and the Spotted Leopard mineral lease.

The width of the outcrops forming the stage is approximately $\frac{3}{4}$ mile, and the average dip of the rocks appears to be at least 45 degrees. The stratigraphic thickness should be at least 900 yards.

Petrography.—The rocks under consideration vary from fine-grained cherty claystones to sandstones of ordinary and quartzitic types.

The quartzitic varieties of sandstone are peculiar, and are only of local occurrence, being due to the introduction of silica along a network of tiny fissures. Where this quartzitic nature is developed, the rock makes a much more decided outcrop than it does along its less silicified portions; in texture it is fine, and in colour greyish to yellow.

The cherty claystones form yellow outcrops, and they are characterised by a peculiar jointing, by means of which they break into small yellow parallelopipeds. These beds, however, frequently weather out in white colours, and the density of the rock is, in such cases, much reduced.

The development of greyish and yellowish-brown claystones is also a feature the C.S.A. stage.

The yellow sandstones of the stage which lie immediately to the west of ıe Cobar township are so strongly cleaved as to present the appearance of ırallel plates arranged at angles averaging about 30 degrees to the strike. leavage planes in coarsely-textured rocks present a different arrangement to ıose developed in finely-textured rocks in association with them. The beds ·e contorted, and the peculiar jointing and cleavage are influenced consider- ɔly by the change of strike of the beds. It is noteworthy that this strong ɜvelopment of cleavage is only visible in those rocks of the group which lie ı proximity to the zone of heavy faulting at Cobar, Fort Bourke, and The eak, whereas the same rocks become somewhat quartzitic towards the .S.A. Mines, without the strong development of cleavage and jointing found ı the more southern outcrops of this area. It is this variability in colour nd appearance of the northern and southern outcrops in this contorted and 'astc-covered system which has caused so much difficulty in mapping the eds and in deciphering their age. They were finally correlated by means of ne band of yellow cherty claystone, which preserved its main features etween the Cobar Hospital and the C.S.A. mine.

The attached petrological description of a sandstone from the group under ɔnsideration is by Mr. G. W. Card:—

"8041. M.L. 57. Parish Cobar.

Sandstone (rather like a freestone).

A fine-grained rock, the constituent grains being just discernible under the lens. It is creamy in colour, jointed, and rudely bedded.

Under the microscope the grain-size is fairly uniform. The grains are irregular for the most part, but a few of them show rounding. No strain phenomena are noticeable. Fine shreds of mica occur interstitially."

Attached is an analysis made of a fireclay belt in this group at the)epartmental Laboratory:—

580–1. Fireclay from 8 chains east of Water Tower.

591.—Rock 8044.

Moisture at 100° C.	0·12
Water above 100° C.	1·58
Silica	86·02
Alumina	9·03
Ferric oxide	0·20
Ferrous oxide	0·27
Manganous oxide	trace (under 0·01)
Lime	0·42
Magnesia	0·34
Soda	0·11
Potash	1·61
Sodium chloride	......
Titanium dioxide	0·48
Phosphoric anhydride	0·03
Sulphur trioxide†	......
Chromium sesquioxide...	absent.
Barium oxide	,,
Strontia	present.*
Lithia	,, *
Vanadium oxide	absent.
	100·21

† 0·07 per cent. of the SO_3 is soluble in water as sulphates of lime and magnesia.

* Spectroscopic reaction only.

(Analysis by Mr. W. A. Greig.)

Age and Correlation.—No determinative fossils have been found in th C.S.A. rock group, but markings occur in them which are suggestive of shel imprints, similar to those of the associated Water Tower Beds. Lithologicall some of the western members cannot be distinguished from certain sand stones and quartzitic types of the Water Tower Group to the immediate west and which are here mapped in as Devonian age. The C.S.A. beds ar possibly, therefore, an eastern member of the great Amphitheatre Series which has suffered more change from the action of the faulting around Coba than the main mass of quartzites, sandstones, and shales lying to the imme diate west. On the other hand, it may be proved by a more extended surve that the C.S.A. beds belong to the Silurian sediments.

The Water Tower Beds.

The rock group under consideration consists of quartzites imperfectl developed, of finely-grained sandstones, claystones, and shales. The averag width of the belt is 220 yards, and the length proved exceeds 15 miles. Th survey of the beds was discontinued to the north at a point about 2 mile north-west of the C.S.A. Mine, while, in the opposite direction, the survey o the same beds was discontinued 7 miles south of Cobar in Henning's Home stead Lease. At the latter locality the belt became highly crumpled, and appeared to be swinging to the south-west as though the whole Amphitheatr Series were forming a huge anticline with its longer axis running from this area and thence on to the Amphitheatre Station. No certain informatio has been obtained as to the position occupied by the Water Tower Beds south of this point, because for several miles around the whole area is merely a waste sheet of very gentle slope.

From this most southerly point the Water Tower Beds pass, in a genera north-north-west direction by way of the show-ground, a little to the west of the cemetery, and the 1-mile peg on the Wilcannia road. Thence they pass within 400 yards to the west of the Water Tower, and cross the Louth road at 4 miles from the town. For a mile farther to the north they form a low ridge, from 30 to 50 feet above the general level, but beyond this for a con siderable distance they disappear under the waste sheet. They outcrop agair in the surveyed village of Elouera, and may be traced thence for several mile to the north.

The beds admit of mapping fairly easily, because, together, they form one of the most resistant rock masses in the field. Two prominent bands of quartzitic sandstone characterise it, the one occurring on the western margir and the other in the centre of the belt. Although the whole width of about 200 yards is mapped in as though visible at the surface, nevertheless the ful width of the beds was observed only over a small portion of the whole length The two characteristic bands of the group, however, are visible over 11 of the 15 miles mapped, and by the position of these the position of the belt itsel has been fixed.

The strike varies very much in detail, but the beds have been mapped in as a whole, regardless of the details of strike variation, so as not to introduce unnecessary complexities into the map. This detailed variation in strike wil be dealt with more fully when considering the related Alley and Biddabirra Beds.

The prevailing dip of the belt is high and almost vertical, the beds dipping at times east and at times west, although the claystones to the immediate east are inclined west at an angle of about 40 degrees about 4 miles north of Cobar.

Petrography.—The rock types vary from fine-grained quartzites and sand-
ones to claystones and shales.

The quartzites appear to derive their character in part from the conditions sociated with their deposition and partly from silica introduced during the ountain-making period which closed the Devonian.

The accompanying description of one of these Water Tower quartzites has :en supplied by Mr. G. W. Card :—

"**8079.** $3\frac{3}{4}$ miles from Cobar, along Louth road.

The rock is of quartzitic type. The constituent particles are just discernible under a lens. There is a slight colouration, and the specimen is traversed by veins of white quartz.

Under the microscope it is seen to consist of irregular interlocking grains, and the whole rock is under strain. While the quartz is the principal constituent, there are some small grains of coloured tourmaline; these are well-rounded for the most part, but crystal faces were shown by one granule. A colourless, highly-refractive mineral is also present in small quantity. A micaceous film envelopes most of the grains."

Mr. Card has here described one of the quartzites which have been still rther altered by the introduction of white to translucent silica along a net ɔrk of tiny veins. In many aces silica may be seen to have ɛen introduced under conditions, obably of heavy pressure, as, for ample, such as would be met with the core of a mountain range. A mmon type of these occurrences herewith reproduced, illustrated ig. 4).

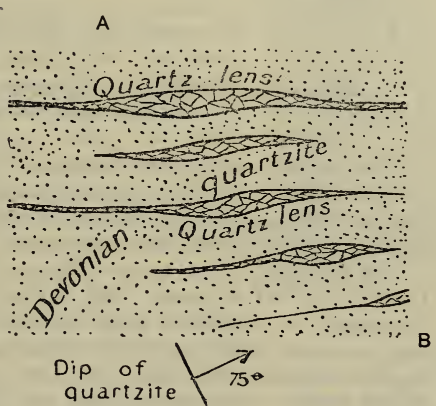

Fig. 4.

Sketch plan of quartz lenses in Devonian (?) quartzite near Cobar. In this interesting type of structure the shorter axes of the quartz lenses are almost collinear.

In this instance a heavy strain pears to have been exerted upon e rock in a direction AB or BA, vertheless the rock has not been ptured, but has, instead, weakened lines arranged almost at right gles to AB. Silica has been troduced in the form of lenses ong these lines of weakness, the nses being so arranged that their orter axes are collinear. This enomenon is suggestive of formaɔn under pressure. Unsupported e tendency would be to sustain pture along the line AB. Similar occurrences are common among the enaceous rocks at Mount Lyell Copper-mine in Tasmania.

The sandstones present many points of resemblance with the quartzites.

Claystones and sandy shales partially cleaved are sandwiched in with the artzites and sandstones. The claystones are grey to slaty-brown in colour, d they break with a subconchoidal fracture, indicating that the slate stage s not been reached.

The Alley Beds.—Commencing as a group of contorted beds, 7 or 8 miles uth of Cobar, in Henning's Homestead Lease, the belt of this name passes a north-north-west direction through several low-lying areas until it crosses e Lerida road $2\frac{1}{4}$ miles south-west of Cobar; thence it may be traced as a ridge to the Alley Trigonometrical Station, the Wilcannia road crossing it i a notch. From the Alley Station it persists as a low ridge to the Coba Water Supply ; here a broad flat valley dissects it, and the strikes of both th Water Supply dam and the Alley Belt coincide. Thence the Alley Beds forn a ridge across the Louth road, about 4½ miles from Cobar, and may b followed for 6 or 7 miles to the north, the continuity of the ridge bein broken, however, by several large yarran flats.

The average width of the belt is 220 to 250 yards, but only a portion o this forms actual outcrops. On the maps the Alley Belt is shown as thoug its outcrop were uniform. In reality, the group possesses a strike markedl irregular in detail, inasmuch as it exhibits innumerable corrugations. On of these exposures is illustrated in Fig. 5.

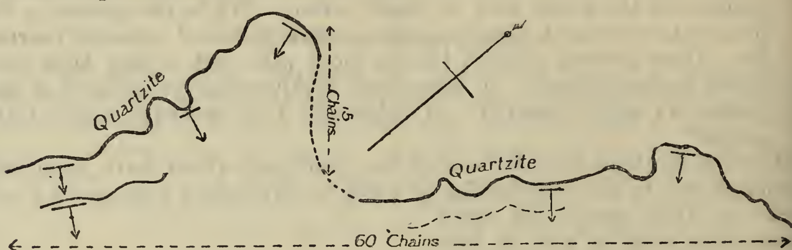

Fig. 5.

Sketch plan of detail of structure in Alley Beds, showing secondary and tertiary folds, 8 miles south of Cobar.

The method adopted in mapping this rock group was to follow one c its more resistant layers, and to estimate the position of the remainder of th belt from the positions of such ascertained outcrops. In this manner th main strike of the belt was ascertained.

The dip is high, and towards the east ; the value of the inclination varie from 60 to 90 degrees. The ridges formed by the outcrops have bee prospected at numerous localities for the purpose of road metal, and th dips have been well exposed in such excavations. Dips thus exposed may b studied especially well along the Louth road, in the by-washes of the Tow Water Supply, and thence along the Alley Ridge as far as the Wilcanni road.

At an early stage of the Cobar survey it was believed that the Wate Tower and Alley Beds represented the eastern and western members respe tively of a denuded syncline. This was because of the similarity in widt possessed by each—the similarity both of lithology and stratigraphic successio of the beds. It was, however, soon noted that the Alley Belt, although onl 60 chains distant from the Water Tower Beds, possesses rock types mor durable than the Water Tower group, that it contains beds full of foss remains, whereas the parallel group is almost devoid of organic remains. I addition to this, the dips of the Alley members are frequent and easily asce tained, whereas those of the Water Tower Belt were ascertained only wit the greatest difficulty.

The fossil bands of the Alley Belt are very persistent, having been trace over a length of at least 12 miles.

The petrography of the belt is interesting—quartzites, sandstones, an yellowish-brown shales being represented. To the immediate east of the be a thin layer of chocolate shales occurs, while a little farther east flattis pebbles of a cherty nature form thin layers. These pebbles in places a strongly crushed and faulted. It is possible, therefore, that hereafter even these Alley Beds may be referred to the Silurian, or even to the Cobar Series, although the fossils and the general lithological characters suggest a Devonian age for the beds.

The quartzites and the sandstones are rather fine in grain, and are frequently traversed by networks of quartz veinlets, from which silicification has extended into the body of the rocks as already described under the head of the Water Tower Belt. Ripple-marks and current-bedding are common in the sandstones, and a few yards to the east of these occur fossiliferous quartzites and sandstones and yellow sandy shales. Of the fossils which occur in great numbers, rhynchonellas, spirifers, and encrinites are common. They are, however, indeterminate, but appear to represent Devonian types. Until more perfectly-preserved forms are found, the age of the beds can only be inferred.

Some of the shale beds in the Alley Belt show slight traces of cleavage. This is the most western point in the locality of Cobar at which the phenomena of cleavage has been observed. Fig. 6 illustrates the incipient cleavage of Alley shales.

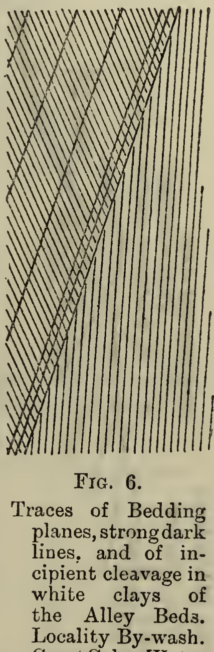

Fig. 6.
Traces of Bedding planes, strong dark lines, and of incipient cleavage in white clays of the Alley Beds. Locality By-wash. Great Cobar Water Supply.

Beyond the Alley Beds, to the west, lie great masses of shales, claystones, sandstones, and quartzites. In these occur the strong belts of fossiliferous quartzite, which cross the Wilcannia road between the 5 and 6-mile pegs, and pass thence through the Lerida Gate, 7 miles from Cobar, whence they disappear under the wide-spread waste sheet to the south. The main mass of the sediments, however, consists of soft sandstones and shales, which are visible on the surface only as small, rounded pieces of clay ironstone in country greatly undulating in character.

The Biddabirra Beds.—The group of this name lies 5 miles to the west of the Alley Beds, and forms a western boundary to the masses of shales and sandstones just described. Quartzites, sandstones, and soft underlying shales form the greater portion of the beds under consideration, and are well exposed in the denuded portions of an anticline, into which the sediments have been folded. This anticline is in the nature of a flattened ellipse whose major axis runs almost parallel to the Wilcannia road between the 7 and 10 mile pegs. At the 8-mile peg the dips of the beds are high, but towards the Amphitheatre head station the anticline may be traced with decreasing dip. It circles the homestead to the south-west in a low bluff of quartzite, and passes sinuously in plan towards the Biddabirra Trigonometrical Station to the east. From this point it winds in a series of corrugations for a mile to the south-east, then sweeps round to the north in an arc of a circle to the Wilcannia road near the 8-mile peg.

Two interesting features connected with this denuded anticline call for special attention, one being the peculiar minor folds which have been superimposed upon the shoulders of the main fold, the other being the great variation in the rock dips. On the general map the folds of the first and second order have been sketched, but the innumerable sharp corrugations which have modified these second-order folds have not been indicated upon the map. The main dips of the anticline, however, have been indicated.

The anticline is of the plunging variety. Its longer axis is about 6 miles in length, and its shortest breadth is about three-quarters of a mile. The minor folds, which break up the even sweep of the main anticline, form embayments from 200 to 800 yards wide at their mouths. These embayments are generally shallow in plan, but the one east of the Biddabirra Trigonometrical Station is deep. In plan the quartzites often have a zigzag appearance owing to the intense crumpling to which they have been subjected. Nevertheless, no cleavage phenomena were observed. Soft and crumbling shales occur immediately underneath the sandstones.

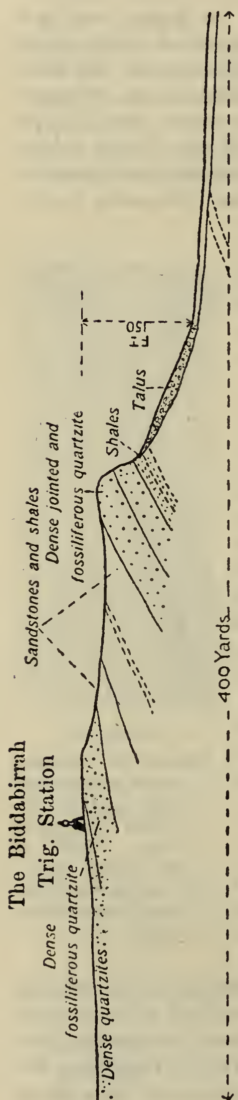

Fig. 7.

Sketch section of detail of succession among Devonian (?) sediments at Biddabirrah Hill, Amphitheatre Station, 10 miles W.S.W. of Cobar.

At the western end the anticline dips at an angle of 30 degrees, thence to the east its dip is fairly uniform for a distance of three or four miles. To the south-east it dips at an angle of not less than 45 or 50 degrees. To the north-east it plunges very steeply, becoming almost vertical between the 8 and 7 mile pegs, while west of its great northern embayment the dip becomes almost negligible for a distance exceeding a mile.

Fig. 7 illustrates a detail in the rock succession of the Biddabirra Beds. The highest members consist of fine-grained whitish quartzites in thick and thin beds. Immediately subjacent to these comes a mass of shales, sandstones, and quartzites about 120 feet wide, measured across the strike. These weather more rapidly than the associated quartzite, and on the surface they resemble a broad road which has fallen into disrepair, while the associated quartzite stands above it like a pavement. A dense quartzite underlies this and forms a steep escarpment about 100 feet in height. The lower portion of this escarpment consists of a talus slope, and the upper portion consists of a cliff.

Petrography.—Massive quartzite is a common constituent, and in such a rock type the dips are obscured. A close examination of the massive quartzite, however, frequently reveals faint traces of bedding planes. Well-bedded quartzite in thin beds is also common. In texture these quartzites are generally fine. The granular structure is easily visible under the lens, and interlocking has taken place. Small fragments of clay or of decomposed felspar form a percentage of the mass. Silicification has been effected in places by the introduction of silica along networks of very small veinlets. Imperfect replacement of the sandstones or quartzites by a whitish form of silica frequently results in the formation of so-called "breccias."*

* A similar phenomon has been recorded by the Writer at Hillgrove and Forbes. *See* Hillgrove Report, "Mineral Resources No. 8," p. 20, and Forbes-Parkes Report, "Mineral Resources No. 13," p. 30.

The shales form very weak belts, and their relatively rapid weathering has produced peculiar topographical forms somewhat similar in appearance to roads between the quartzite bands, the latter rising as low ridges or pavements above the sunken roads according to the prevailing dip of the quartzite beds. Another instructive feature is the peculiar jointed appearance of the dense quartzites forming the Biddabirra escarpment. The first impression gained upon examination is that the escarpment is dipping at an angle of about 70 degrees to the north, and that the slope of the escarpment coincides with the bedding planes of the quartzites. The apparent bedding planes are, however, a system of powerful joints, inclined to the north. The true dip is into the hill and away from the escarpment at an angle of about 30 degrees. Still another set of strong vertical joints, arranged in a north and south direction, has been developed in the quartzite. Under the influence of weathering huge columnar blocks thus break away from the face.

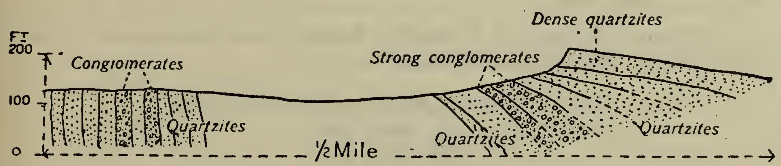

FIG. 8.

Sketch section across Devonian sediments at Wittagoona, 40 miles W.N.W. of Cobar.

Still farther west a long north and south line of Devonian conglomerates and sandstones occurs. Fossils are very abundant. Rhynchonella cuboides, var., and Strophomena are the commonest types. The sediments appear to represent a shore-line in Devonian time.

Figs. 8 and 9 illustrate details of rock succession at two widely-separated points in this line of Devonian sediment.

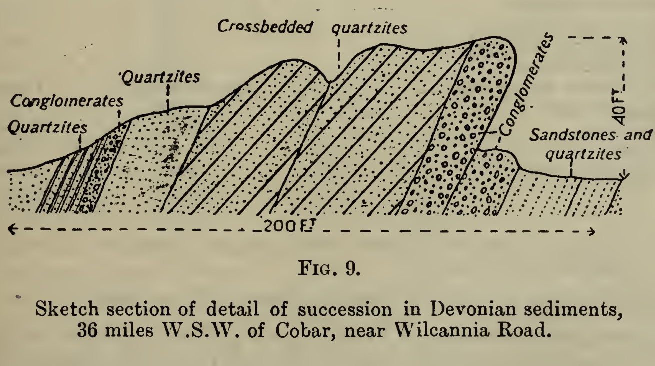

FIG. 9.

Sketch section of detail of succession in Devonian sediments, 36 miles W.S.W. of Cobar, near Wilcannia Road.

Condition of Deposition.—From the foregoing descriptions it is probable that this vast thickness of alternating shales, sandstones, quartzites, and conglomerates, and known as the Amphitheatre Series, and containing abundant traces of brachiopods, encrinites, and other forms of life, represents sedimentation on a shallow and slowly subsiding area.

Age and Correlation.—Mr. W. S. Dun refers the Amphitheatre Series to the Upper Devonian. The following list of fossils obtained from rocks of this age at Cobar has been determined by the same authority :—

Favosites ; Indeterminable Tabulate Coral ; Crinoid Stem Ossicles ; *Chonetes, Athyris* (?), *Rhynchonella cuboides* (?); *Spirifera*, cf. *octoplicata* ; *S.*, cf. *Jarqueti, Tentaculites.*

The specimens are preserved as impressions and casts on ferruginous and whitish quartzites, recalling the Devonian boulders of the Whitecliff opal fields, with which they may probably be correlated.

In lithological characters, the series resembles the Devonian rocks of Parkes, Forbes, Orange, and Rydal. Each consists of great thicknesses of quartzites, sandstones, claystones, and chocolate and greenish shales. The fossil traces become rarer as one goes eastwards across the Amphitheatre Series, and the eastern members of the series have been correlated with the Devonian on lithological grounds alone.

Attached is an analysis of a fireclay found 7 miles west of Cobar, and occurring in the Amphitheatre Series :—

580 1. —Fireclays from 7 miles west of Cobar.

580—Rock 8042.
581—Rock 8044.

	Analysis by Mr. W. G. Stone. 580–8042.	Analysis by Mr. W. A. Greig. 581–8044.
Moisture at 100° C.	1·39	0·12
Water abover 100° C.	3·89	1·58
Silica	65·65	86·02
Alumina	21·11	9·03
Ferric oxide	0·95	0·20
Ferrous oxide	0·27	0·27
Manganous oxide	trace.	trace (under 0·01).
Lime	0·31	0·42
Magnesia	0·70	0·34
Soda	0·16	0·11
Potash	4·40	1·61
Sodium chloride	0·26	......
Titantium dioxide	0·80	0·48
Phosphoric anhydride	trace	0·03
Sulphur trioxide*	0·18	......
Chromium sesquioxide	minute trace.	absent.
Barium oxide	0·09	,,
Strontia	†trace.	†present.
Lithia	†trace.	†present.
Vanadium oxide	trace.	absent.
	100·16	100·21

*0·07 per cent. of the SO_3 is soluble in water as sulphates of lime and magnesia.
† Spectroscopic reaction only.

Sediments not yet correlated with any known Cobar beds.

Twenty-five miles eastward of Cobar a group of ore deposits occur associated with altered sedimentaries such as crumpled siliceous schists, quartzites, phyllites, and allied rock types. These appear to be pre-Silurian in age, and resemble the Hermidale, Nymagee, and Restdown schistose rocks in general appearance.

A few miles south and west of this point a peculiar group of tuffs, breccias, claystones, and slates form small outcrops.

The following petrographical descriptions of two of these rock types have been supplied by Mr. G. W. Card. No. 8162 is from this group, 25 miles east of Cobar, while 8175 is from Rabbit Hill Mine, 27 miles east-south-east of Cobar.

"**8162**—Boppy Broken Hill Mine; quartzose phyllite.—A pyritous, dark, greenish-grey rock. The planes of schistosity show a certain amount of satiny sheen, but the feature is not a pronounced one.

"Under the microscope, there is much quartz, a good deal of which shows undulose extinction. Mica occurs along the planes of schistosity, and also finely disseminated through the rock. The quartz grains are angular, they are under strain, but are not shattered.

"An acicular colourless mineral is present, the nature of which has not been determined."

"**8175**—Rabbit Hill Mine; breccia.—Colour of rock, mottled green, red, brown, and grey.

"Numerous fragments lie in a matrix, displaying a silvery sheen. These appear to consist principally of grey slate and granite material; they are of varying shapes and dimensions, 10 mm. being an approximation to a commonly occurring size.

"Under the microscope, the matrix appears to consist of finely aggregated mica. One of the slate fragments is studded with crystals of pyrite. The felspar of the granitic particles is little altered, and consists of broken orthoclose and oligoclase.

"The rock seems to be a volcanic breccia."

IGNEOUS ROCKS.

The only igneous rocks known in the whole of the Cobar District are the two small "pipes" in Parish Narri, about 13 or 14 miles in a south-south-east direction from Cobar. One lies about half a mile to the east of the Queen Bee Mine, the other about 1¼ miles to the south-south-east of the same mine. Both "pipes" are small and lenticular in plan. The northern "pipe" is about 13 chains in length, and the extreme width is 2½ chains. The longer axis of the southern "pipe" is 12 chains in length, and the shorter axis, 4 chains, while the longer axes of the individual "pipes" lie almost at right angles to each other. The mass to the north is encircled by Cobar sandstones, which rise about 2 feet, like a collar, above the "pipe." On the other hand, the southern exposure lies at the junction of slates and sandstone, and forms a slight eminence above the surrounding sandstones and slates.

Other interesting points in connection with these igneous intrusions lie in the fact that both are practically devoid of vegetation, while the surrounding sandstone of the northern example is clothed with dense growths of mallee (*E. Morrisii*), *Prostanthera Leichardtii* and Sifting Bush (*Cassinia*). The colours of the two rock exposures present great differences, that of the southern occurrence being characteristically black, while that of the northern one is yellowish to brownish yellow. The southern one weathers like a granite, the northern one outcrops only as a mass of rotten porphyritic material. In each type the rock may be described as a felspar porphyry. In the northern example the southern portion is composed of a whitish-grey quartz-felspar porphyry, with a fine-grained matrix, the crystals not being conspicuous. In the northern portion of the same "pipe" the felspar crystals are large and white, and are readily detachable from the surrounding decomposed matrix. It is difficult to secure perfect specimens of the large crystals, because of the strong jointing to which they have been subjected.

In the southern "pipe" the appearance from a distance is that of a mass of sediments dipping steeply to the west. This is due to the peculiar set of joints which cause the rock to weather out in the form of some shark-fins or canine teeth. Plate 19 illustrate this jointing and other surface phenomena of the "pipe."

The following petrographic descriptions are by my colleague, Mr. G. W. Card :—

"8288–8289. Bee Mountain Gap.

"Quartz-felspar-porphyry.

"From southern margin of 'pipe.'

"A light grey mass, weathering to deep pink through the mass, and to a yellow crust. Pyritous. Conspicuous phenocrysts of quartz and felspar are present. The felspar is creamy to white, many good automorphs being obtained ; the cleavage is good, so also is the lustre of these felspars. The phenocrysts reach an inch in length. The groundmass exceeds the phenocrysts in volume. The fracture is even to sub-even.

"Under the microscope the felspar is seen to be orthoclase, rather clouded. The quartz is corroded and embayed under strain, and some of it is elongated by pressure. Shattering of the quartz is also noticeable. The groundmass is micro-crystalline. Secondary quartz in veins is present, and this is also under strain."

Below is an analysis of this rock, carried out at the Departmental Laboratory.

"8076. From small dyke, about 100 feet to the north-west of northern end of 'pipe.'

"This rock type is not conspicuously porphyritic. Its colour is bluish-grey, weathering to a red crust. The fracture is uneven. Phenocrysts are small and sparse. Pyrites have been developed in the mass.

"Under the microscope the rock is porphyritic. Phenocrysts of lime-soda felspars lie in a groundmass of microlitic felspar. The whole is somewhat clouded, and flecks of green and non-pleochroic material are scattered throughout the mass."

"8105. Quartz-oligoclase porphyry. M.L. 8 ; 14 miles south-east of Cobar. Occurrence, a small 'pipe.'

"In hand specimens, and under the lens, the rock is seen to be dark grey, and conspicuously porphyritic. The phenocrysts in the aggregate are approximately equal in volume to that of groundmass. The felspar crystals are white, cleaved, twinned, lustrous, and frequently exceed an inch in length.

"Quartz is as plentiful as felspar, but is not readily seen against the dark groundmass.

"The fracture is uneven ; secondary quartz and pyrites are present."

Below is an analysis of this rock carried out at the Departmental Laboratory.

Under the microscope the quartz is seen to be corroded, embayed, and shattered. Strain phenomena, however, is but slightly exhibited. The felspar is oligoclase, showing slight clouding.

A little biotite is present, and is partially decolourised with separation of iron ores. Grains of opalite are enclosed.

Photo. M. Sullivan.

Weathering of Orthoclase-porphyry in Small " Pipe," 1½ mile South of Queen Bee Mine.

Photo. M. Sullivan.

Small Orthoclase-porphyry " Pipe " in Foreground, Queen Bee Mountain (Sandstone) and Mine in Distance.

The groundmass consists of microlites of felspar, with flecks of a greenish mineral which is practically non-pleochroic.

Analyses of material, both from the pipes and the large orthoclase crystals, are attached:—

955-11.—Orthoclase (picked from the pipe rock 8105) from 14 miles south of Cobar.

(Calcite present.)

Water	0·57
Silica	59·45
Alumina	17·68
Ferric oxide	0·65
Ferrous oxide	0·45
Lime	4·43
Magnesia	0·21
Soda	2·36
Potash	11·08
Titanium dioxide	0·07
Carbon dioxide	3·25
	100·20

Including any phosphoric anhydride present. Specific gravity, 2·566.

(Analysis by Mr. W. G. Stone.)

From the field and the petrological notes here presented, the two igneous masses under consideration may be classed as denuded "pipes," the age of the intrusions coinciding most probably with the post-Devonian folding, and immediately prior to the period of ore deposition.

953-11.—Quartz-orthoclase Porphyry from Bee Mountain Gap, Cobar.

Silica	78·16
Alumina	11·01
Ferrous iron	0·10
Ferric iron	0·63
Magnesia...	0·15
Lime	0·30
Soda	0·36
Potash	7·97
Water at 100° C.	0·21
Water above 100° C.	0·17
Carbon dioxide	absent.
Titanium dioxide	0·32
Zirconium dioxide	absent.
Phosphoric anhydride	0·07
Sulphur trioxide	absent.
Chlorine	0·04
Fluorine	absent.
Iron sulphide	0·45
Chromium sesquioxide...	absent.
Nickel and cobalt oxides	,,
Manganous oxide	trace.
Barium oxide	0·18
Strontium oxide	absent.
Lithium-oxide	,,
Vanadium oxide	,,
Copper oxide	trace.
	100·12

Specific gravity, 2·589.

(Analysis by Mr. W. A. Greig.)

954-11.—Orthoclase Porphyry, M.L. 8, 14 miles south of Cobar.

Chemical Composition.

Silica	69·90	
Alumina	14·09	
Ferric oxide	0·88	
Ferrous oxide	2·33	
Magnesia	0·98	
Lime	1·10	
Soda	2·35	
Potash	5·99	
Water at 100° C.	0·10	
Water above 100° C.	1·00	
Carbon dioxide	0·40	
Titanium dioxide	0·40	
Zirconium dioxide	absent.	
Phosphoric anhydride	0·19	
Sulphur trioxide	......	
Chlorine	0·03	0·04
Fluorine	absent.	
Iron sulphide	0·02	
Chromium sesquioxide...	absent.	
Nickel and cobalt oxides	absent.	
Manganous oxide	0·02	
Barium oxide	0·02	
Strontium oxide	present	spectroscopic reaction.
Lithium oxide	present	
Vanadium oxide	absent.	
Copper oxide	0·01	
	99·81	

Specific gravity, 2·649.

(Analysis by Mr. W. A. Greig.)

Structure.

General Statement.—The Cobar district is a worn-down mass of crumpled Palæozoic rocks. Silurian, Devonian, and systems possibly even older than these, are represented. No junctions between the various systems have been observed.

All the rocks represented in the field are strongly folded. Great faultings appear to have accompanied the folding, and such dislocations are most noticeable in the vicinity of the lodes. The rock alterations (by reason of earth movements) have also been most pronounced near these planes of movement.

The Silurian sediments appear to have been folded at the commencement of the Devonian Period, while the Devonian sedimentation itself closed with a vigorous mountain-making movement, accompanied by heavy overthrusting or shearing in zones, along which the Cobar lodes were deposited.

Folding.—The rocks of the Cobar area appear to have been affected by at least two folding movements. The Cobar Series, consisting of crushed conglomerates, quartz schists, sandstones with "eye" structures, schistose slates, and well-cleaved slates, evidence the greatest alteration from the effects of earth movements; while the Amphitheatre quartzites, sandstones, and shales of Devonian age, which evidence less stress than the rock systems to the east, apparently mark a still later and less intense movement.

Cleavage and Augen Structures.—These are only developed in the vicinity of the main lodes, and in places appear to die out into the surrounding Silurian and Devonian systems. This suggests that such forms are due mainly to local intensity of movement. Shearing of pebbles is not confined to rocks of the Cobar Series, but occurs indifferently in the rocks of the Weltie, the Cobar, and the Amphitheatre sediments. The "drawing out" of pebbles into long lenticular forms is, however, confined either to the Cobar Series, or to still older sediments.

Age of Folding Movements.—Commencing with the youngest sediments, namely, those of the Amphitheatre Series, it is evident that a powerful movement must have closed the period of deposition, inasmuch as no traces of carboniferous rocks occur in the whole district, and because in New South Wales—with the exception of areas in the north-east portions of the State—all sediments younger than Devonian are practically horizontally bedded.

Within the area mapped no observed dips of the Amphitheatre sediments were less than 30 degrees, except at one place, namely, the long plunging anticline, near the Amphitheatre Station. On the other hand, very steep dips are common. Minor folds have been imposed upon the larger ones, and sharp corrugations, in turn, have been imposed upon the minor folds. Fig. 5 illustrates this. See also the plan of the plunging anticline on the general map.

The folding of the Weltie Beds and the Nyngan road cherts is more pronounced than that which has affected the Amphitheatre Series. It is possible, however, that the weaker structures of the Mallee Tank and the Nyngan road cherts are more susceptible to compression than those of the Amphitheatre quartzites and sandstones. It is impossible, with the evidence available, to make an accurate representation of the relation of the Mallee Tank and associated beds, as the dips and the strike vary very much, considered from point to point, while the cherts, shales, and sandstones have been thrown into such unsymmetrical anticlines and synclines as to make it difficult to determine the prevailing direction of the rock dips.

It is to the east of the Cobar field that the schists are developed, while at Cobar itself slaty cleavage and a minor development of "eye" structures in the sandstones are the most pronounced signs of metamorphism. To the west of the Cobar lodes the phenomenon of rock cleavage appears to die out instead of ending abruptly.

There are two possible explanations of the association of the schists, the "eye" structures in the sandstones, the perfect and imperfect slates and other products of rock metamorphism.

(1) There may be a mass of Silurian schistose rocks associated with a series of younger Palæozoic sediments almost devoid of cleavage phenomena as a whole, but showing cleavage in the vicinity of heavy faultings.

(2) There may be a great mass of older Palæozoics which evidence the effects of variable alteration. Thus intense alteration is shown over an area lying from 20–70 miles east of Cobar, while at Cobar itself the metamorphism is not nearly so marked. This may arise from the wearing down of a great mountain range, at whose core the alteration was pronounced, but whose borders were not altered to nearly such an extent as the central portions.

Dislocations due to Folding.—Of the dislocations due to the foldings which occurred prior to the close of the Devonian sedimentation, nothing is known, such movements being obscured by the post-Devonian folding. The dislocations referable to this later compressive movement are, however, of the highest importance. To them attention may be directed at this stage.

Faulting.

Character and Distribution of Faults.—The main faults appear to possess high dips, and their maximum development occurs in the area containing the lodes; nevertheless it may hereafter be proved that faults equally large with those now to be described occur in portions of the field not yet examined in detail. In addition to the large dislocations, there are great numbers of minor cross faults apparently of the normal type. These may be dismissed with the briefest mention, inasmuch as they have neither caused serious difficulties in tracing the lodes, nor have they in any marked degree determined the secondary enrichment of the ore bodies.

The main dislocations considered in the present report are the Queen Bee Lode, the Blue Lode, the Great Peak Fault, the Occidental–Chesney and the Fort Bourke Faults, the Great Cobar, Gladstone, and the C.S.A. Lodes.

The evidence of faulting will be presented with each description. The faults are described as they occur in order on a westerly traverse.

The Queen Bee Fault.—This fault is an important one, and it has been traced for a distance of about 2 miles. Topographical evidence of the dislocation consists in the association of hills of dense sandstones abutting against

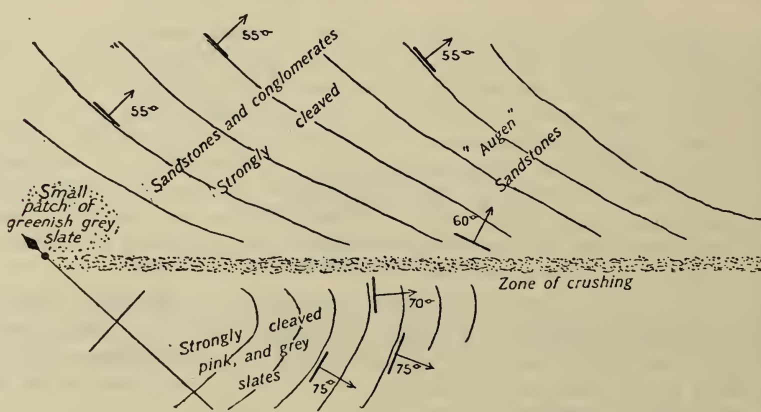

Fig. 10.

Sketch plan of structural detail, about 20 chains north of Main Shaft, Queen Bee Mine. Sediments much altered, bedding planes obscured by strong earth movements.

low-lying areas of slates. The geological evidence for the existence of a fault is as follows:—The Mount Nurri sandstones rise suddenly from the plains south of The Rookery, and run thence in a north-westerly direction for a distance of about 10 miles. A mile north of the Queen Bee Mine the sandstones are bounded to the west by red slates and small patches of conglomerates and sandstones. At the Bee Mountain itself (a rough broad ridge about 150 feet in height) the western foot of the sandstone mass is occupied by a strongly-crushed mass of slate and allied material in which fragments of a crush breccia appear to have been drawn out frequently into thin flat silky forms. The eastern side of the lode is occupied by dense sandstones, whose dip is easterly, while the strike is almost north and south and at an angle of 35 degrees to the sandstone and slate junction. The strikes of both sandstones and slates swing into the lode as they approach it, and the dips of the sediments on the opposite sides of the lode are opposed. Fig. 10 illustrates this point. Although the dip of the sandstone is opposed to that of the lode and the fault, nevertheless at a depth of about 700 feet the sandstones have not reappeared on the western side of the lode. This, then, indicates a fault with a heavy throw. The lode has been developed along the fault zone. The topography suggests that this fault extends for many miles to the south under the waste sheet.

The Blue Lode and Fault.—The "Blue Lode" consists of two fissures, of which the western member appears to be continued northerly as The Premier, Lady Greaves, The Peak Prospecting Area, and other lodes. Along its southern end it separates altered slates from well-banded sandstones and coarse sandy slates. The soft grey slates lie to the west, while the coarser types form an anticlinal structure to the east. The continuation of this fault in the Premier leases separates grey slates from hard green sandstones or arenaceous tuffs, while to the north of the Premier leases the fault separates green and dense grey argillaceous sandstones from each other. On the map and in the field both of these types appear to be collinear, but this is probably a coincidence only. Both are sandstones possessing exceedingly high angles of dip, but the green type is hard and rings under the hammer, and shows no "augen" structures in the sand grains, while the greyish-brown type is more cleaved, it weathers out in much more angular forms than the green rock, and it shows traces also of "augen" structures. The variation in colour and hardness of these collinear sandstones may, however, be due to a local introduction of silica into the sandstones. The fault plane passes under the waste sheet to the north.

The plane of movement is not difficult to trace, inasmuch as it is occupied by a quartz vein which has been worked for gold. The dip of the sediments is westerly, and that of the fault is easterly.

Although the field evidence here mentioned is such as to indicate a dislocation, it is not sufficient, on the other hand, to indicate the amount of throw. Distinctive rock types and well-defined beds of sediment are characteristically absent from the district. Moreover one has only the shallow mining workings upon which to rely; the outcrops of sandstone at the Peak are very limited in size, and nowhere else in the field have similar greenish sandstone been observed, except at the Bee Mountain and Mount Drysdale.

The Peak Fault.—Neglecting a number of minor dislocations to be seen near the Trigonometrical Station itself, and others exposed in the cross-cuts and open cuts of the Brown and Conqueror Mines, attention may be directed next to a strong line of dislocation extending from a point south of the Great South Peak Gold-mine for a distance of at least 2 miles to the north. This may be traced along the surface both by the occurrence of quartz bands and by a zone of crushed slate. The latter appears in places to be made up of small parallel plates of satiny material caused by the development of secondary mica, and of other material arranged in planes parallel to the general planes of dislocation. The cleavage parallel to the general planes of dislocation is so distinct that it is mistaken for bedding planes by the mining community.

The fault may be of much greater length than as mapped, because it disappears both north and south of the Peak under a waste sheet.

A little to the south of the Great South Peak Mine, it may be traced as a strong quartz vein. Hence it passes through the Perseverance blocks and mining leases containing the Brown and Conqueror lodes. In this portion of the area a great width of slate has been shattered and mining operations reveal the presence of a series of parallel quartz veins and a strong development of crushed and cleaved slate.

About 10 chains northerly along the line of fault from the Great Peak Gold-mine battery, the fault zone is seen to narrow and to separate a mass of dense argillaceous sandstones from a belt of greyish cleaved slates. The western sandstones here abut on the plane of dislocation in a series of knobs which, although very small, form quite a distinct surface feature. The roughly curving lines of the dense sandstone to the north-west may be seen to bend round to the fault as they approach it. These coarse stony bands are covered with luxuriant growths of *Prostanthera Leichhardtii*, and both stony bands and plants end suddenly at the insignificant quartz line which parallels the hillside. The sandstones at this spot rise about 2 feet above the soft grey slates to which they suddenly give place. The occurrence is rather puzzling at first glance, because the dips of the argillaceous sandstones have been almost obscured by the strong earth movements while the pronounced cleavage and jointing planes suggest bedding traces. From a distance of 50 yards, however, it is possible to make out the strike easily. With careful examination also the bedding planes may be distinctly traced.

The junction of similar sandstones and slates may be traced to a point about 40 or 50 yards west of the Great Silver Peak Shaft. At this point the main plane of dislocation appears to pass in a parallel direction about 50 yards to the east and along this eastern line the Great Silver Peak Mine is situated. Much crushing is evidenced hereabouts.

Northwards of the Great Silver Peak Mine, the Peak fault is bounded on each side by sandstones and slates. A decided doubling back of the sandstones on to the fault plane was noted in P.G.Ls. 20 and 21, and in G.L. 153. This feature is indicated on the map.

The sandstones on each side of the fault possess varying strikes and a general westerly dip of varying value. The fault, on the other hand, dips persistently at a high angle (65° to 80°) to the east. Farther north the zone of crushing disappears beneath the waste sheet.

No approximate estimate can be made of the amount of throw possessed by this dislocation. No sandstones quite answering the description of those covered by the *Prostanthera* growths occur upon the Peak itself. If, however, the sandstones of P.G.Ls. 20 and 21 be considered as the equivalents of those in M.Ls. 9 and 11, then the amount of horizontal displacement is about 3,500 feet. On the other hand there are various reasons why these two sandstone occurrences may not be considered as discontinuous portions of the same belt. In the first place no *Prostanthera* shrubs grow on the northern sandstone, whereas they are characteristic of the southern mass, both being equally well situated with respect to the needs of the plant. Indeed it is surprising how this plant* selects the one type of rock upon which to grow to the exclusion of other types. In the second place the more southern sandstone group has a more siliceous and ferruginous appearance than the northern group.

It is probable that the throw of the fault under consideration is very large.

With regard to its origin the evidence suggests an overthrow fault. This consists of the marked incurvature of the beds on both sides to the fault plane, the strong development of cleavage in planes parallel to that of dislocation, and the crushed appearance of the zone containing the fault plane as the other points.

* *Prostanthera Leichhardtii* grows also upon the south side of the Bee Mountain, upon sandstones almost indistinguishable from those at the Peak. Nowhere else in the district has this plant been found.

OCCIDENTAL GOLD MINE.

Sketch Section across the lode

from measurements supplied by the Mine Manager

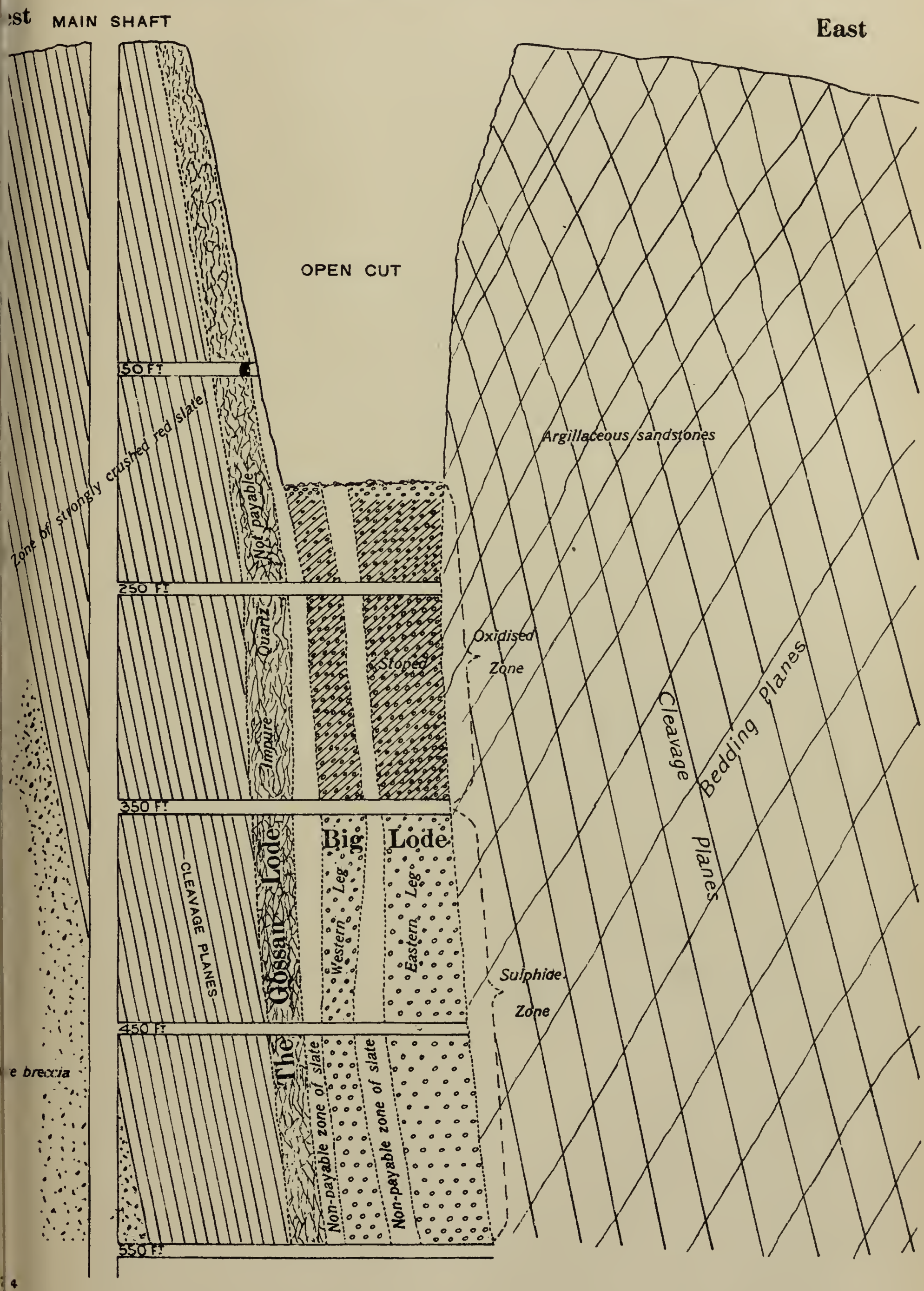

PHOTO-LITHOGRAPHED BY W. A. GULLICK, GOVERNMENT PRINTER, SYDNEY, N.S.W.

The Great Chesney Fault.—This line, as mapped, extends from a point well south of the Occidental Mine to the Tharsis, a distance of at least 5 miles. It may be considered either as one line showing a break at the Fort Bourke Hill, or it may be considered as two faults, one the Chesney-Occidental line, the other a subparallel distributary of the Chesney dislocation, or as a subparallel continuation of the main Chesney dislocation. The northern member embraces the Cobar Gold, Fort Bourke, Freehold, and Tharsis fissures.

Occidental–Chesney Section.—From M.L. 11, near the Peak, a sandstone and slate junction may be approximately traced for ¾ of a mile north-west to P.G.L. 36. At this point there are indications of a zone of crushing under the waste sheet, the sandstone and red slate junction approximately defining the position of the zone. A considerable amount of prospecting has been carried on in this area for a continuation of the Occidental Lode. At the Occidental Ridge, however, the signs of faulting become much more pronounced. On the east side of the Occidental Lode, and thence all the way to the Young Australian, the strike of the sandstones is inclined at an angle varying from 5 to 15 degrees to the general direction of the lodes. Moreover, mining operations reveal the fact that all the sandstone dips in the vicinity of the lode are very high, and in a westerly direction. On the other hand, the long line of lode dips steeply to the east; nevertheless, the sandstones have not yet been found on the western side of the lode, nothing but red, yellow, and grey slates. Fig. 11 and Plate 19 illustrate this feature. In addition to this, the Occidental, Young Australian, and Mount Pleasant lodes lie in a heavy zone of crushing. The crushing, however, is more evident in the slate to the immediate west of the lode proper. One of the phases of faulting appears to be marked by the "Gossan Lode" rather than by the more important eastern ore bodies in association with the "Gossan," or siliceous, lode. Subparallel movements appear to have occurred in the sandstones to the immediate east. This is generally evidenced by the development of quartz-veins parallel to the zone of crushing in the slates. Distributary fissures are common in the form of smaller quartz-veins having a general strike to the north-west.

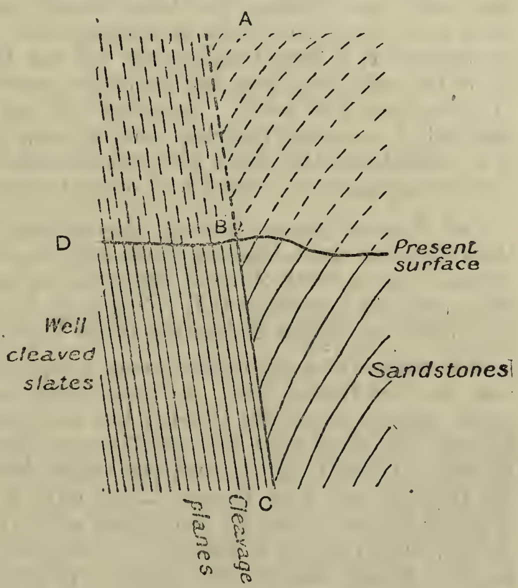

FIG. 11.

Sketch section to illustrate the structural relations between the sandstones and the slates in the neighbourhood of the Occidental–Chesney Fault. The bedding planes of the sandstones are seen dipping against the general mass of the slates.

At the Mount Pleasant Mine the sandstone and fault strikes are almost coincident.

Thence the fault may be traced through the Chesney Leases. As at the Occidental Mine, the main ore bodies do not appear to coincide with the plane of strongest movement, but rather to represent replacements of crushed slate masses in the vicinity of the main fault. The directions of sandstone and lode outcrops is here different, the former striking almost north-west, and the lodes about north 18 degrees to 20 degrees west. The dips of sandstones and of lodes are always opposed, yet the sandstones never cross to the western side of the lode. From the Chesney main shaft to the southern slope of the Fort Bourke Hill the sandstones almost parallel the lode, but their dips are opposed to those of the lodes. It must also be borne in mind that the area under consideration has been strongly denuded since the formation of these lodes along these zones of crushing, and unless a powerful dislocation be conceded it is difficult to account for the fact that, despite the westerly dip of the sandstones they end suddenly against the zone of crushing. Fig. 11 illustrates this point. Inasmuch as the sandstones have been much denuded, it is evident that they must, at some previous period, have extended in a vertical direction above the present surface. Thus, unless a dislocation ABC be assumed, it is difficult to account for their absence along BD.

Fort Bourke–Tharsis Section.—Immediately northwards of the Chesney Open Cut, the great Chesney Fault becomes broken up apparently, and distributed over a width of about 200 yards and a length of 800 yards. About 500 or 600 yards north of G.L. 159 it again is concentrated into a strong line, and carries on the line of fracture to the Freehold Mine.

It is evident at a glance that some complex action has taken place at and near the Fort Bourke Hill. At its northern end the sandstones have crossed to the western side of the Chesney line continuation, but have failed signally to cross the subparallel and neighbouring line of lode, known as the Fort Bourke or Cobar Gold. In each case the sandstones have been faulted against the Chesney and Fort Bourke Lodes, as in M.L. 171 and C.L. 48 (see map of Cobar Mines), where the sandstones and allied rocks possess north-western strikes, while the lode is about N. 180 degrees west. Both the Chesney and the Fort Bourke fissures thus appear to represent dislocations, but the main action here appears to have suddenly passed a little to the west, at the Fort Bourke fissure. In each case the sandstone dips are high and in a westerly direction, while the lodes dip in an easterly direction. All the country to the west of the Fort Bourke fissure consists of red slate.

Numerous veins cf quartz intersect the country between the Fort Bourke and the broken Chesney lodes. These probably represent the occupation of strain fissures by silica.

Near the southern portion of G.L. 52 the Chesney and Fort Bourke lines appear to approach closely, and thence they may be traced to the Freehold. A zone of crushed slate marks the trace of the dislocation, while sandstones form the eastern, and slates the western, wall. The strikes of lode and sandstone are variable, although a little distance to the east, along the Nyngan road, the strike of the sandstones is nearly north and south.

At the Freehold Mine the fault passes under an alluvial flat for a considerable distance, but reappears, in all probability, at the Tharsis Mine, to the north of the railway line. Here also the sandstone and slate junction is close to the lode on the east, and the sandstones do not cross to the west of the lode.

The constant westerly dip of the sandstones against the planes of the lodes may be natural, but in this area of crumpling and dislocation it is regarded rather as a result of the faulting or dragging of the eastern sandstones over and against the western slates. In this connection it may be here stated that the dips of the sandstones, at some distance from the lodes, is not always in a westerly direction, whereas those alongside of the lodes are uniformly to the west wherever observed.

In one place a so-called breccia was observed, namely, at the Occidental Mine, in a zone adjoining the "Gossan Lode" on the west. Usually the result of heavy movement has been to develop zones of crushed slate, with well-developed cleavage, in planes parallel to those of the main lodes. The calcite "breccia" is younger than the main faulting movement.

The Great Cobar Lodes.—The evidence for the fault origin of these features is not nearly so satisfactory as in the case of the Bee, the Peak, and the Occidental–Chesney lines; and the argument is based mainly upon analogy. In the Great Cobar property a series of large lenticular ore bodies are arranged along a line almost parallel with the Fort Bourke and Chesney fissures. The dips are practically identical in each case also. Subparallel fissures accompany the Great Cobar on the east, much in the same manner as the parallel veins to the east of the main Chesney and Occidental lodes. To the north of the railway line these ore lenses pass into a series of veins, which outcrop either as quartz or as siliceous gossans. About a mile north of the Great Cobar a couple of strong quartz-veins appear to represent the continuation of the fissures under consideration.

To the south lie the Gladstone outcrops of siliceous gossan. These offset the Great Cobar outcrops slightly to the east, but, nevertheless, they appear to represent the earth movement which was most intimately related to the Great Cobar fissure in a southerly direction.

With regard to the evidence of faulting gained from a study of the country rock at the Great Cobar Mine, it is known that a siliceous red slate occurs to the east of the Great Cobar ore lenses. This slate is neither so soft nor so "blocky" as the class of slate forming the western wall. The observed dips were at high angles to the east, the cleavage planes were also dipping at a high angle (+ 70°) to the east, and the fracture is subconchoidal. On the west, as seen in the cross-cuts and in the large "mullock" tank, the slate is mainly red, of a softer nature and "blocky." Where observed, its dip was at a high angle to the west, and the cleavage was at an equally steep angle to the east, and the fracture was clean, or, in other words, the cleavage was almost perfect.

The lode itself is nearly vertical, but appears to have a slight easterly underlay. This easterly underlay is noticeable in the Great Cobar North.

From a consideration of the variation in the character of the eastern and western slates, and of the apparent variability in the rock dips of these two country types, from a consideration also of the general similarity in direction and dip of the lode with others in the district, and from a consideration of the large lenses of ores of replacement formed along this line of lode, as well as from a knowledge of other but subordinate characters, it is highly probable that the Great Cobar Lode lies in a plane or zone of decided movement.

A number of siliceous and ferruginous gossans and of strong quartz-veins traverse the township of Cobar. It is probable that these also indicate lines of powerful movement. Stratigraphic evidence of faulting, however, is almost lacking in this locality, owing to the lack of rock exposures. These outcrops in the town area have been prospected in some measure, but none of them have yielded returns of gold or silver worthy of consideration. For copper they do not appear to have been prospected.

The C.S.A. and Tinto Faults.—This group comprise several fissures in close association. All the lodes in this area (about 7 miles N.N.W. of Cobar) lie along subparallel fissures, all of which have practically the same strike and dip as the fault planes already described. The lode material also is similar to that of the other veins of the district. The dips of the western and eastern country also appear to be opposed.

On the other hand, cleavage, crush zones, and allied phenomena are almost absent.

If, as seems probable, the C.S.A. and Tinto Lodes represent the introduction of sulphides along planes of dislocation, then the testimony of the rocks themselves is that such movement of dislocation decreased decidedly in intensity to the north of Cobar.

Cross Faults.—These are numerous, but do not appear to have had much influence upon the ore deposits. They will receive attention in the descriptions of the lodes themselves.

The Age of the Faulting.—The main faulting which determined the ore entries did not occur before the close of the Devonian Period. The evidence for this is of a double nature, and depends upon a knowledge of the ore deposits themselves, which were deposited along or near the planes of movement, and upon a knowledge of the age of the country rocks.

If the Bee, The Peak, Chesney, and Great Cobar Lodes which traverse the altered Cobar Series had been formed in the pre-Devonian time, then they must have been heavily folded and faulted themselves during the great deformation which appears to have closed the Devonian sedimentation in the Cobar district. On the other hand, the lodes of the district are almost undisturbed, and mining operations are singularly free from difficulties generally experienced in areas of even moderate vertical uplift.

In the second place, the mineral associations in the lodes are very similar, and point to a common age for the main faults. It is true that the Great Cobar lode is basic in character, and that the Fort Bourke, Chesney, Peak, and Bee Lodes possess acid gangues. It is true, also, that the more westerly of the lodes, such as the C.S.A. and the Great Cobar, are more distinctly of the cupriferous pyritic types than the eastern lodes, nevertheless, the mineral association is very similar in all. Thus an almost identical class of pyrrhotite occurs along the long Fort Bourke and Chesney line of lode, the Great Cobar, the C.S.A. and the Tinto mines. Galena and zinc-blende of very similar types occur in all the lodes.

The striking general parallelism of the faults also points strongly to the formation of all during one and the same period.

The C.S.A. and Tinto Lodes occur in the Amphitheatre Series, and the age of all, therefore, may be placed in the post-Devonian. The evidence of the faults in the altered rocks of Cobar, however, is such as to strongly suggest their formation during a period of heavy faulting accompanying mountain-making. Inasmuch, also, as Carboniferous sediments are absent from the Cobar district—for, with the exception of the New England area, no other folding period, accompanied by heavy dislocations, has taken place in New South Wales since the commencement of Carboniferous time—the great faulting period under discussion may be placed at the close of the Devonian sedimentation in the Cobar district.

At a later period the faulting action was revived, and the hanging-walls of most of the lodes appear to have subsided. By this movement the C.S.A., Tinto, Great Cobar, The Peak, and Queen Bee Lodes were most affected.

On the other hand, if the C.S.A. Beds should hereafter be ascertained to be Silurian, it may be that the lodes will be found to be early Devonian in age; but if the Cobar deposits were formed in pre-Devonian time it is difficult to account for the absence of faulting exhibited by these deposits during the folding which closed the Devonian sedimentation.

GEOLOGICAL HISTORY.

The western district of New South Wales is not well known geologically, and the present map of Cobar will serve only as a nucleus for future work in that area. The notes here presented must therefore be taken only as tentative, because the characteristic absence of natural exposures in the Cobar district can only be balanced by extending the observations beyond the present area as mapped. Especially needful is it to extend such observations to the north-east, east, and south in the vicinity of Canbelego, Restdown, Nymagee, and Shuttleton.

The earliest records in this area apparently extend to lower Palæozoic time, when a mass of argillaceous and quartzose rocks had been accumulated in a great depression over the north-eastern, eastern, and south-eastern portions of the large Cobar district. At a later period these sediments were intensely folded and crumpled, the result of such action being the production of quartz schists, quartzites, and argillaceous schists. By the folding action which formed these high Palæozoic mountains around Girilambone and the country to the south, a depression was formed simultaneously in the western portion, and an epicontinental sea was formed over the Cobar area.

Then came the reduction of this high eastern land. At first the streams were rapid, and they carried large pebbles and boulders toward the shallow Cobar sea. The compact and interlocked quartzites offered the greatest resistance to the stream action, and great masses of such material were carried on to the shore and redistributed by the waves and currents to form dense conglomerates. In this way the Dijou, Drysdale, Queen Bee Mountain, Restdown, and still more southerly conglomerates, were formed. The general position of these pebble and boulder beds marks the old and retreating shore-line of that time.

In proportion as the mountains became dissected the streams lost their early power, and conglomerates gradually gave place to sandstones. With still greater reduction of the land, and with increasing depth of water and sinking of the sea base, the sandstones gave place to fine muds and shales, of which a great thickness was deposited. Coral reefs also flourished in this sea.

This period of sedimentation appears to have been closed by an upheaval, a period of compression, and a still more marked down-warping of the Cobar and still more southerly areas. A remarkable series of alternating shales, sandstones, and cherts were formed in this sea. The exact origin of the cherts is unknown. Certain it is that ordinary rock metamorphism was not the cause, inasmuch as they are associated with weak shales and soft sandstones, the bedding planes of neither cherts, shales, nor sandstones being at all obscured. It is possible that these thin and numerous chert bands were derived from the precipitation of silica by means of organisms. For discussions of the possible origin of other similarly occurring rocks, the reader may read a paper on the "Whetstones and Novaculites of Arkansas," by L. S. Griswold, in the Annual Report of the Geological Survey of Arkansas, 1892; and a paper on "The Origin of Certain Novaculites and Quartzites," by F. Rutley, Q.J.G.S., 1894, pp. 377–392. Speaking of the origin of cherts, Professor von Hise says, in his treatise on "Metamorphism," pp. 847–853:—

> "I am inclined to believe that it may largely be an organic precipitate, although now completely recrystallised, so as to be composed of perfectly-fitting granules of quartz."

At a still later period the epicontinental sea appears to have increased in area in the district under discussion, and in this sea the later Devonian sediments were deposited. They appear to have extended almost continuously to the west of a line joining Coolabah, Canbelego, Nymagee, and Mount Hope. These are represented also by isolated masses to the east and south-east of Cobar itself.

One magnificent shore-line of Devonian age extended from a point near Louth southward for at least 70, or even 100 miles. The pebbles of this shore-line are composed of opaque and white quartz pebbles, in contrast with the translucent grey quartzite pebbles of the conglomerates belonging to the Cobar Series.* In the Devonian sea a great thickness of alternating sand and shale beds accumulated, and this suggests a gradually sinking sea-bottom. Brachiopods and encrinites flourished in this shallow sea.

The Devonian sedimentation closed with a vigorous compressive movement, the sea area was converted into dry land, and there is no evidence to hand to show that in the immensely long period which has transpired since the momentous Devonian that the Cobar area has ever again been subject to marine invasion.

A mountain range was formed by this movement, and a strong local earth movement so affected the earth's crust that a series of great dislocations formed along north and south lines from Cobar and Mount Boppy to Mount Hope. In this way great masses of the older rocks appear to have been thrust up among the younger Palæozoic sediments, and along the lines of weakness thus formed the famous Cobar Lodes were deposited by ascending solutions charged with silicon, iron, copper, and sulphur.

On the mountain masses thus formed the streams commenced their task of denudation. Several times they were interrupted in their attempts to reduce the whole area to a monotonous plain by relatively slight elevations of the land, but no other mountain range has since been formed in the area. For a long period the land has been an almost featureless plain, only relieved by the outcrops of the quartzites, sandstones, and the lodes which formerly had lain in the heart of the mountain mass.

As the lodes were attacked the more superficial ore deposits were rearranged so as to form rich masses of copper near the outcrops, while a little below water-level the ore deposits apparently remain in the state in which they were first deposited.

In late geological time the climate of Cobar gradually appears to have become sub-arid.

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* The existence of these two massive conglomerates—one of Devonian, and one of Silurian age—suggests that the Silurian sediments have a much greater extension west than at present assigned to them on the map. This point can only be cleared up by future mapping.

Chapter IV.

THE ORE DEPOSITS.

History.

The details of the history of Cobar mining have been supplied in the Chapter on the General History of the District and in the descriptions of the various mines.

Distribution of the Ore Deposits.

The ore deposits which have been proved to be of most importance in the Cobar area are arranged approximately *en echelon* from the Queen Bee Mine in the south-east to the Tinto and C.S.A. Mines in the north-west. The General Map illustrates this arrangement.

The most important of the ore bodies occur within a distance of 4 miles of Cobar, and are confined to a very narrow strip of country.

South of the Queen Bee Lode, and on the same line, a moderate amount of prospecting has been carried out for copper and gold, but nothing of value has been found in this southern portion of the district.

At the Bee Mountain, one portion of the crushed zone showed kindly gossans and carbonate stains. To the north the crushed zone is seen, but with very little traces of gossans.

About 3 miles to the north-west of the Bee Mountain, prospecting for gold and copper has been carried on at the Beechworth, Coronation, and Central Mines, but with only moderate success.

The Peak is riddled with veins containing gold and crushed material. These have yielded gold and silver, but the copper values are negligible.

Parallel with this line, to the immediate north and west, lie the collinear lodes of the Occidental, Young Australian, Mount Pleasant, and Chesney. Copper occurs along the whole line, but the mines have been worked for gold rather than for copper.

The Cobar Gold (old Fort Bourke), the Fort Bourke, the East Cobar, the Freehold, and the Tharsis lodes are practically continuous with the Chesney line. Gold and copper are won in the Cobar Gold Mine, but gold is the most important product. Neither the Fort Bourke, the East Cobar, the Freehold, nor the Tharsis are payable at present. Copper values occur in all.

To the west of the Cobar Gold Mine the Gladstone Mine has been recently opened up. Its line is parallel, but a little eastward, of the Great Cobar. Rich copper values are being obtained from this lode at and near water-level. The lode is surrounded by slates on both sides.

The most important producer in the district is the Great Cobar Lode, which outcrops as three lenses of gossan, the middle one showing copper carbonate stains. The country at the surface is red slate, and the minerals worked are copper, gold, and silver.

Siliceous gossans pass through the lenses of the Great Cobar North, and these represent the northern extensions of the lodes in the shattered country adjoining the Great Cobar property. A careful search is being made along one of these lines for copper values. The country is slate.

The C.S.A. and the Tinto lie 7 miles to the north-north-west of the Great Cobar Mine. Large lenses of gossan were observed there in the early days of the field. Copper stains also were found in the large boat-shaped outcrop of the C.S.A. lode proper. A rich patch of carbonate of lead was struck at a depth of about 430 feet, and subjacent to this a large and lean mass of cupriferous pyrites was proved by shafts, drives, and cross-cuts. Smaller and more siliceous copper veins were found to the east of these basic bodies. The country is mainly of claystone nature.

The gossans proper are thus seen to occur in the western portion of the field, while the long lines of siliceous gossans and of quartz lodes occur east of these in turn. Characteristically the eastern lodes are gold producers, while the western examples are more of the nature of copper and lead lodes.

The payable mineral deposits occur generally on the western aspects of the gentle rises which diversify the surface of the Cobar Plain.

Although the ore deposits are apparently post-Devonian in age, nevertheless, in the case of all save the C.S.A.–Tinto–Spotted Leopard line, the ores occur in the Cobar Series and at the contacts of either different types of slate or of slates and sandstones. The Cobar Series has been already described, and reference is here made merely to its altered appearance as compared with that of rocks in this district possessing a definite Devonian facies. The C.S.A. line of lode is the only one of importance which has been proved to occur in rocks, which are similar in lithological character to those of known Devonian age in the district. In rocks of definite Devonian age no ore deposits of any importance have been found. The question also arises, namely, "May not the cleavage and other metamorphic phenomena observed in the vicinity of the more important lines of lode be due to local intensity of movement, acting upon Silurian and Devonian sediments?" In this connection, also, it is singular that at a distance of from 1 to 2 miles from the main lodes, little or no trace of cleavage is to be found, whereas in the heaviest-known faulting there the cleavage is perfectly developed.

General Classification of the Ores.

The ores of the Cobar District may be classed as:—

(1) Cupriferous ores with varying gold and silver contents.
(2) Gold ores free from copper.
(3) Silver-lead ores.

The gold and silver deposits proper, are subordinate in importance. On the other hand, they throw light upon the genesis of the lodes, and thus they will receive attention in the proper place. The Peak veins are interesting types of the gold and silver-lead veins, while the Coronation, Central, and Beechworth Mines, a little to the south-east of The Peak, represent an area in which gold has been distributed unevenly.

The copper ores may be divided into—

(*a*) Oxidised ores; and
(*b*) Sulphide ores.

Oxidised Ores.—These were relied upon in the earlier days of the field, when the ore was shipped to Adelaide by way of the Darling. These oxidised masses were rich at and above water-level, but could not be depended upon below that depth. Some of the oxidised ores occur *in situ*, but others appear to have travelled downwards after oxidation from sulphides.

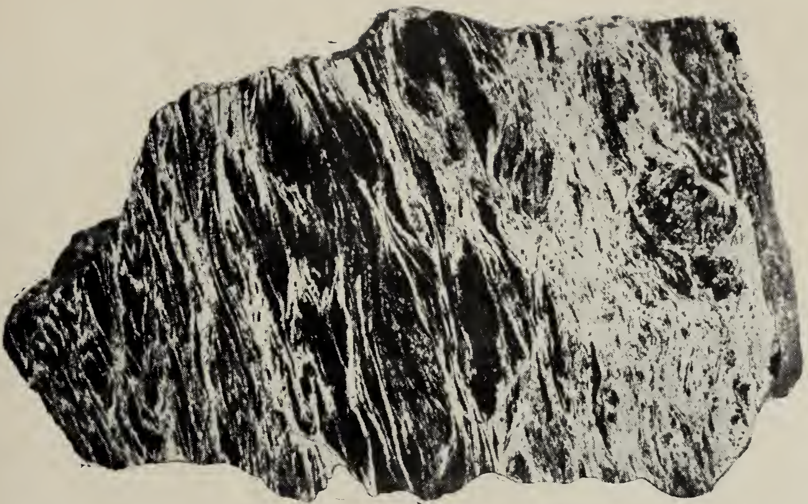

Photo. Govt. Printer.

Fig. 1. Replacement of Slate by Pyrrhotite, No. 9 Level, Great Cobar Mine, Western Wall.

Pyrrhotite, white ; *Slate*, black.

Photo. Govt. Printer.

Fig. 2. Nodules of Marcasite in Pyrrhotite, Great Cobar, No. 9 Level, Western Wall.

Sulphide Ores.—These were found early in the prospecting campaign, but, with the exception of the richer masses of chalcocite and chalcopyrite, the sulphide ore bodies were not exploited until the erection of water-jacket furnaces.

The sulphide ores appear to be capable of further division into ores of primary and secondary deposition, or into ores due both to original precipitation and those due to the concentration of the ores of original precipitation by wandering descending waters. Thus, in the Great Cobar Mine, water-level occurs at a depth of about 280 feet, in the south end of the mine. Grey sulphide of copper (chalcocite), occurs in abundance on both No. 3 (230 feet) and No. 4 (320 feet) levels, but not on No. 2 (150 feet). Between Nos. 3 and 4 levels, along the northern lens, rich yellow sulphide was found up to within 20 feet of No. 3 (230 feet). The assay value of this ore was 23·9 per cent. copper, 39 per cent. iron, 32 per cent. sulphur, and 1·9 per cent. insoluble, according to the assays made by the chemists of the Great Cobar, Limited. The width of this mass was 17 feet.

Now, at moderate depths below water-level, these rich masses of copper sulphides disappear, their places being taken by a mass of cupriferous pyrrhotite, containing about 2·5 per cent. of copper, as shown by the treatment of about 2,000,000 tons of ore.

Mineralogy of the Ores.

No rare minerals occur in the Cobar District, and the mineralogical character of the ores is rather simple.

It may be advisable to consider the sulphides in the first place.

These consist of pyrrhotite (magnetic pyrites), iron pyrites, chalcocite (copper glance, "grey" ore), chalcopyrite ("yellow" ore, copper pyrites), galena, and zinc-blende.

Pyrrhotite occurs in great quantities in the lower levels of the Great Cobar and Tinto Mines. In 1912 it was found in the C.S.A. Mine. It is rather rare in the Cobar Gold, and Chesney, and Occidental Mines, and it has not yet been recorded from The Peak or the Bee Mines.

Characteristically, it forms solid masses of compact and finely granular material, of a bronze-red colour. In some places the pyrrhotite has the appearance of a cementing material to fragments or so-called breccias. (Plate 22.) This, however, in many places represents an imperfect replacement of slate by pyrrhotite along a network of veinlets.

Iron pyrites is common in some, and practically absent in other mines. It occurs generally in the massive form, but it may also be found as cubes in the country of rock. Interesting nodules of iron pyrites and marcasite occur on the western portion of the Great Cobar Lode. The nodules are flattish (Pl. 21, Fig. 2), and the iron sulphide composing them is of the granular type, the matrix in which they are set being a compact and massive form of pyrrhotite.

In the C.S.A., Tinto, and Queen Bee Mines the iron pyritic content is especially large.

Chalcopyrite (copper pyrites) is the commonest sulphide of copper. It is the only copper ore found at any except moderate depths below water-level in the Cobar district. It occurs in massive forms as veins of compact and apparently textureless material, as coarsely granular or as feathery aggregates, and as tiny lines. It is bright yellow in colour, and has few impurities.

Galena and zinc-blende are present in almost every mine in the district. The galena is generally compact and finely granular. It also forms feathery aggregates and veinlets. The coarse platy and cubical varieties are rare. Zinc-blende is commonly of the finely granular variety, brownish in colour.

Native Minerals.—Native gold, silver, copper, and bismuth are found in the district. As a rule, the gold occurs in the free state above water-level, and some of the copper-mines of the district were worked primarily for gold. Below water-level the precious metal is usually intimately associated with pyrites of various types. The gold occurs as grains, in small wiry masses and other forms, and it is yellow in colour.

Native silver occurs as wires, and as irregularly-shaped aggregates in the Great Silver Peak, C.S.A., and Tinto Mines.

Native copper is found as thin tough plates in the C.S.A. Mine, and as plates, wires, and delicate forms like strings of beads, in the Gladstone and other mines.

Native bismuth occurs in the Great Cobar Mine. A specimen in the Museum of the Department of Mines (lent by Mr. W. H. Trewenack) shows large and irregularly-shaped fragments of bismuth associated with crystallised magnetite. A granular and streaky variety occurs in the Occidental Lode, associated with the gold-bearing magnetite "Indicator."

In the early days of the field bismuth is said to have caused trouble in the casting of copper. In those days reverberatory furnaces were used, in which the oxidation of the metals was not so great as in the smelters used at the present time. Bismuth does not occur in such quantities as in former years in Cobar, and no trouble is now experienced with this mineral. Moreover, a great amount of oxidation takes place in the more modern types of converters.

Oxides.—Cuprite occurs as fine-grained and very dark red masses, sometimes as adamantine and blackish-crimson masses. Impure earthy varieties of brick-red colour are not uncommon. Crimson translucent cubes also occur. The mineral is common in all the copper-mines at and near water-level.

Magnetite, although an oxide of iron, does not belong to the zone of oxidation, but occurs in the sulphide zone. The reason for this is dealt with fully under the head of Mineral Paragenesis. It occurs in masses and well-cleaved forms, but this is rather rare, as its general habit is massive and granular. Masses of this mineral, slightly admixed with chalcopyrite, pyrrhotite, and slate, are as much as 50 feet wide in places. It occurs also in the Chesney Mine, and in the Occidental it occurs as thin parallel veins on the east side of the main lode. As in the Great Cobar it is there associated with pyrrhotite and a primary silicate of iron. Magnetite was expected in the Cobar Tinto, but was not found there.

Hæmatite, at Cobar, occurs in the oxidised zone and not in the primary ore zone. In the Cobar district it is always associated with limonite, native copper, cuprite, malachite, and azurite.

Limonite is very common as brown or yellow masses of impure nature, or as stains, all the forms being characteristically developed in the oxidised zone.

Carbonates and other forms.—Malachite was fairly abundant in the upper mine levels of the district. Immense bunches of brilliant green malachite are recorded from the Great Cobar Mine. Mammillated, concentric, mossy, and other forms were also abundantly represented. Near the surface of the outcrop of the Great Cobar Lode, malachite occurred as veinlets or stringers, which had the appearance, according to the miners, of "rivers on a map." It occurs also in vughs.

Azurite occurs as large blades, as arborescent forms, and as crystals in small vughs. Large radiating masses of the mineral have been obtained also in the Great Cobar Mine. It is common, also, as stains and as masses of irregular shape in the Bee, the Young Australian, the Mount Pleasant, the Chesney, and the Cobar Gold Mines. Its common associate is malachite.

Chloride of silver occurs as yellowish-green crystals in vughs and joints in the Great Silver Peak. In places this mineral is found sitting upon a rich, velvety-brown gossan. Small quantities of the mineral occur also in the C.S.A. and Tinto Mines in association with carbonate of lead and brown gossan.

Carbonate of lead is fairly plentiful in the Great Silver Peak, the Tinto, and the C.S.A. Mines. It is generally massive, radiating or crystalline in character. Beautiful crystals of pyramidal shape are fairly common; these possess a pearly lustre.

Carbonate of iron occurs in massive form at Rabbit Hill, and as thin veins in the Occidental, in association with magnetite and iron silicate.

Ekmannite (?).—A peculiar silicate of iron has been found along both walls of the Great Cobar lode. The occurrence is in the nature of long blades and fibres of a shining blackish-green mineral in a setting of ordinary whitish quartz and silicified slate. It occurs also in a similar association, both in the Great Cobar North, at 1,450 feet depth, in the Occidental Mine, and in the Cobar Gold Mine. It is found only in the primary zone of ore deposition.

The following description of the mineral has been supplied by my colleague, Mr. G. W. Card:—

893 (Rock 8052), from No. 10 Level, Great Cobar.—Silicate very near Ekmannite.

Analysis.

Water at 110° C.	0·33
Water above 110° C.	8·75
Silica	44·20
Alumina	5·66
Ferrous oxide	31·23
Ferric oxide	5·10
Magnesia	1·96
Lime	0·48
Soda	0·46
Potash	2·05
Phosphoric anhydride	trace.
Titanium dioxide	do
Manganous oxide	do
Copper pyrites	do
	100·22

NOTE.—Treatment with hot acid liberates all the silica without gelatinisation.

(Analysis by Mr. H. P. White.)

Description of Mineral.

Colour: Greenish black; streak much lighter—greyish green.
Hardness: Less than 2.
Lustre: Almost metallic.
Structure: Massive and lamellar. In places forms interlacing plates. Lamellæ usually close set and parallel, forming a sort of vein in the massive variety. Lamellæ normal to the containing walls.
Copper pyrites present.

In Dana's "Mineralogy" (1892, pp. 662, 663), Ekmannite is described as an associate of magnetite at Grythytte, in Sweden, filling cavities in ore.

Quartz is exceedingly common. It fills veins, and also forms large replacement masses through the whole district. It varies from colloid to glassy types, and from tough to brittle varieties. It is generally massive, but sometimes forms crystals in vughs. It may be milky, opaque white, brownish, grey, or bluish in colour. Pseudo-breccias are formed in places by the imperfect replacement of slate or other rock types by silica.

Magnesite occurs in nodules as much as 15 inches in diameter. These are formed at the surface in the slates, shales, and allied rocks. Such magnesite has generally formed at the expense, in part, of the associated rocks.

Calcite is common in some of the mines; for example, the Tinto, the Occidental, and the Mallee Tank. It is massive, radiating, and crystalline in character. It occurs generally as veins and as a cement to replacement breccias.

Paragenesis.

The association of the minerals of ore deposits and their gangues, with special reference to the sequence and method of their formation, is known as paragenesis.

Of the list of minerals described under the previous subheading it is found that the limonite, malachite, azurite, cuprite, native copper, native gold, native silver, chloride of silver, carbonate of lead, chalcocite, and rich bunches of chalcopyrite characterise the upper portions of the lodes, while these give place at moderate depths below water-level to masses of iron pyrites, pyrrhotite, chalcopyrite, magnetite, Ekmannite, gold and silver in pyrites, and galena, zinc-blende, and quartz. The list of these minerals which occur typically below the water-level may be subdivided again into minerals of various periods of ore introduction. The pyrrhotite, magnetite, iron silicate, and associated chalcopyrite form the older group, while the galena, iron-pyrites, zinc-blende, calcite, and the chalcopyrite associated with them, appear to represent a younger group of ore bodies.

Primary Minerals.—Those minerals which may safely be classed as primary in this district consist of pyrrhotite (magnetic pyrites), magnetite, silicate of iron, chalcopyrite (in part), native bismuth, galena, and zinc-blende (in part), iron pyrites, carbonate of iron, and quartz, in part. Galena, zinc-blende, and iron pyrites are associated with pyrrhotite, magnetite, iron silicate, and bismuth, but they appear to be of more recent age than the latter. Chalcopyrite appears to belong to both periods of ore deposition.

It has been stated already that iron pyrites appears to be of primary nature, but of later origin than the pyrrhotite and magnetite. This statement needs modification, inasmuch as certain bodies of iron pyrites in the district appear to belong to the same age as the pyrrhotite masses. In such cases, however, pyrrhotite is absent. Ordinary massive iron pyrites is exceedingly common in some mines, such as the Bee, the C.S.A., and the Tinto, while in others it occurs in cubical form, thus clearly betraying its origin by replacement of other minerals. In the Great Cobar Mine ron pyrites also occurs as nodules in the form of ellipsoids andspheroids.

Chalcopyrite also occurs as veinlets along slate joints (Plate 26), and as strings and as bunches in quartz (Plate 25). It occurs also in granular aggregates.

In the Great Cobar Mine chalcopyrite, magnetite, and pyrrhotite form the bulk of the ore. Chalcopyrite is associated with quartz and slate (with pyrrhotite, magnetite, and iron silicate as rather rare accessories) in the Chesney and Occidental Mines; with massive iron pyrites in the Queen Bee; with pyrrhotite and with still younger iron pyrites in the Tinto Mines; and with massive iron pyrites in the C.S.A.

Galena and zinc-blende are common in the C.S.A. and Tinto Mines below water level. Their associates are iron pyrites, pyrrhotite (magnetic pyrites), quartz, calcite, and slate. In the Great Cobar Mine the galena and zinc-blende are of decidedly later age than the cupriferous pyrrhotite. Chalcopyrite and iron pyrites, on the other hand, appear to have been introduced with the galena and zinc-blende.

In the long Chesney-Occidental line of lode, as also in the intimately related Cobar Gold lode, both galena and zinc-blende occur. Similar associations of lead and zinc sulphides also occur in the Great Silver Peak Mine.

In the Cobar field galena and zinc-blende are characteristically associated with iron pyrites and not with pyrrhotite. Both iron pyrites and pyrrhotite occur together in almost all of the mines, but wherever evidence of a double period of ore entries is present, there the iron pyrites, the galena, and the zinc are decidedly younger than the pyrrhotitic bodies.

Magnetite occurs either crystallised or as great masses of granular material associated with massive pyrrhotite. These primary massive ores represent replacement of slate and allied rocks, and the origin of their interesting association is reserved for discussion under the heading "Genesis of the Ores."

Secondary Ores—Sulphides.—Chalcocite (copper glance) always appears to be of secondary origin at Cobar, and the presence of rich bodies of chalcopyrite (yellow ore) in certain places may also be explained by the processes of secondary enrichment.

Chalcocite.—This rich ore rarely occurs at any but slight depths below the water-level, and it forms large masses at and near this zone of permanent saturation. At greater depths it is replaced by chalcopyrite with iron pyrites or pyrrhotite. Chalcocite may be seen replacing chalcopyrite, the latter being left as tiny kernels in a mesh of the "grey" ore. This sulphide appears to have been the last formed.

Chalcopyrite.—The evidence for the secondary origin of certain rich masses of this ore is not so definite as it is for the case of chalcocite. In the Great Cobar Mine, however, the average value of the lower levels is rather less than 3 per cent. of copper, while that of the great masses of "yellow" ore near water-level exceeded 17 per cent. copper, although the mineral mined in each case was chalcopyrite in the main.

Oxidised Ores.—These are partly of later, and partly of simultaneous, origin with the secondary sulphides.

Cuprite and native copper occur with chalcocite and chalcopyrite at and near water-level. The native copper forms at times from the cuprite and separates out as plates and wires along joints or through chalcocite and quartz. Cuprite also replaces chalcocite in turn. Malachite also appears to replace chalcocite, chalcopyrite, and cuprite. The exact relations of malachite and azurite have not been determined; but in specimens from the Young Australian Mine, azurite may be seen enveloping malachite and forming strings throughout it. On the other hand, masses of radiating azurite are seen to contain nests and strings of malachite throughout them. Other specimens again suggest that these minerals have developed side by side.

In one specimen from the Gladstone Mine the chalcocite may be seen replacing chalcopyrite, while malachite, in turn, has formed crusts and strings around and through the chalcocite,

In another specimen malachite has formed a crust of weathering round a large block of cuprite and has developed small nests inside the mass.

A third block of ore contained numerous films and knots of native copper, which had formed along joints in cuprite, while malachite in granular masses had formed apparently at the expense of the more siliceous portions. Specimens such as this are frequently quite tough by reason of the great development of native copper along tiny joints in the cuprite and quartz.

Carbonate of lead forms at the expense of galena above water-level. Native silver and chloride of silver are associated with the carbonate of lead and rich brown gossan.

Silica is very abundant, and has been introduced during the whole process of ore deposition. Its influence has been relatively weak in the Great Cobar and C.S.A. Mines. It has replaced large masses of slate and sandy slate country. Frequently the result of this replacement process is the production of a siliceous slate or sandstone, which weathers into a siliceous gossan at the surface.

Calcite, like silica, appears not to have been limited to any single period of ore deposition.

Magnesite has been formed partly at the expense of the associated slates and claystones.

Limonite is a very common mineral. The western lode of the Great Cobar Mine outcropped as a brownish-limonite gossan associated with quartz. The outcrops of the two lodes lying to the immediate east of the main vein consist of siliceous limonite gossans, and these may be traced as such through the property of the Great Cobar North.

Siliceous limonite outcrops similar in appearance to those just mentioned are fairly common in the field. Examples of such are the Queen Bee, Peak, Occidental, Mount Pleasant, Chesney, and Fort Bourke outcrops.

The C.S.A. and Tinto lode outcrops are of the nature of large impure limonite masses, the impurities consisting of silica, altered claystones, and other material.

"Ironstone blows" are of frequent occurrence in the Cobar district; they consist of masses of impure siliceous limonite, generally of a reddish or a dark-brown colour. These have all been prospected for gold, silver, or copper. Generally, however, it is ascertained, during prospecting operations, that the "ironstone" at shallow depths passes into whitish and grey slates, sandstones, claystones, or shales. This impure superficial limonite appears to be due in great measure to the action of capillary attraction on underground waters in arid countries, whereby material in solution is drawn to the surface and there precipitated by evaporation, instead of being transported to the neighbouring watercourses. This action has been dealt with more fully in another chapter (pp. 30-32).*

Partial replacement of the slates and sandstones of Cobar is common. In these instances the bedding plane traces contain the major part of the limonite content.

Limonite occurs also as a matrix to some of the copper and gold ores occurring near the surface.

Hæmatite occurs as a secondary product in the lower oxidised zone, and its usual associates are chalcocite, cuprite, native copper, and traces of copper carbonates. Cavernous limonite is also an associate in some mines. At times it is difficult to distinguish between the earthy forms of cuprite and hæmatite.

* See also E. C. Andrews, Forbes-Parkes Gold-field, "Mineral Resources N.S.W.," No. 13, p. 21.

As showing the peculiar association of these secondary minerals in the Cobar district, it may be interesting to mention the sequence of minerals observed in the Gladstone Mine—a mine in which the primary ores have not been reached as yet.

Along the 260 feet level (deepest workings) a rich quality of chalcopyrite occurs as veins and masses in a rotten slate gangue. The ore is generally of the peacock variety, and is frequently coated with a sooty copper sulphide. About 25 feet above this level the rich chalcopyrite gives place to a reddish sandy and incoherent mass, apparently a ferruginous sandy aggregate. A mass of cavernous reddish-brown limonite also about this point occurs at times to a depth of 4 feet and a width of 18 inches. This limonite contains a high percentage of native copper as knots, strings and wires, and it is a matter of difficulty to break the limonite mass, even with a heavy hammer, by reason of this native copper content. Just above this, rich chalcocite occurs, generally forming on kernels of chalcopyrite, and showing masses of earthy hæmatite and cuprite in association. These rich masses of chalcocite ("grey ore" of the Cobar miner) extend thence to water-level (195 feet), and near this level itself magnificent bunches of the chalcocite occur, associated with malachite, azurite, and cuprite.

Above a point 180 feet from the surface the rich chalcocite passed into small patches of copper carbonates. Practically the whole cap of the lode above 180 feet depth consists of a non-payable siliceous gossan.

In the Great Cobar Mine itself a similar sequence of minerals was passed through, only that the masses of chalcocite and chalcopyrite, with the accompanying sooty sulphides, copper carbonates, cuprite, native copper, and hæmatite, were much larger than those of the Gladstone example.

Geological Occurrence of the Lodes.

The whole of the ore bodies of the Cobar District may be classed as lodes, the term lode not being used in the American acceptation of an ore body occurring between definite walls, but rather in conformity with its use in Australia to denote lenticular or irregularly shaped masses of ore due mostly to replacement agencies.

All the lodes have been formed along fault fissures already described on pages 68 to 74. Each main fissure has been associated with numerous distributaries and subparallel minor fissures. Only a few of the veins thus formed have yielded payable results. Quartz occupies many fissures in which deposition of payable minerals has been practically absent.

The general trend of the lodes is north 15° to 22° west, and their dips are almost uniformly east at angles varying from 60° to 87°.

An interesting feature in connection with the lodes is the apparent dying out of one example in a certain direction, and its continuation in a parallel direction a little to the east or west of the original trend. Thus the Chesney line appears to be continued by the Fort Bourke system, which is picked up a little to the west of the Chesney line, and this without any direct evidence of cross-faulting.

One or two examples of this action also occur at the Peak, and a similar action is suggested by a study of the C.S.A. and Tinto lodes.

Another point of interest is the association of one main line of lode with one or two minor parallel lines. Two lodes may also be parallel to each for a certain distance and then merge into each other at both ends. The Bee and the Occidental exemplify this phenomenon.

The Queen Bee, Great South Peak, Brown, Conqueror, Blue, Premier, Great Silver Peak, Occidental, Young Australian, Mount Pleasant, Chesney, Cobar Gold, Fort Bourke, Freehold, Tharsis, Gladstone, Central, Coronation, and Beechworth are the main lodes of the district. The siliceous gossan outcrops which may be traced through the leases of the Great Cobar and Great Cobar North are examples of subordinate lodes.

The Queen Bee is a compound fissure vein in crushed slate at the junction of argillaceous sandstones and slates. It consists in the main of two parallel fissures from which replacement of the country has proceeded, the fissures meeting at certain points.

The Peak veins are in sandstone and slate along lines of crushing, and they consist of gold quartz and silver lead.

A consideration of the Occidental, Chesney, and Fort Bourke lines shows that complex fissuring has occurred, with local replacements of country along the lines of shattering. At the Occidental a series of several parallel veins occurs. The westernmost of these is the Gossan Lode, a wide mass of impure ferruginous quartz, arising in part from a replacement of slates, and whose western wall consists of heavily crushed slates. To the east of the Gossan Lode, within a distance of 70 feet, two lodes occur. These consist of silicified slate containing gold and copper, and they are separated by non-payable slate "horses." The mass is nearly 200 yards in length, and tapers from a width of 70 feet in the centre to a narrow belt north and south. East of this altered country lies a parallel quartz vein named the Albion. Sandstone forms the country east of the main payable lode.

At the Young Australian and Mount Pleasant (present Cobar Copper Company, Ltd.), the siliceous Gossan Lode is associated with parallel lodes to the east. The lodes occur at the junction of sandstones and slates.

A similar association of parallel lodes is to be seen at the Chesney. Here the usual lens of payable ore has been formed at the expense of the red slates. This lens exceeds 1,000 feet in length, is from 35 to 40 feet in width on an average, and has a very steep dip.

The Cobar Gold (old Fort Bourke) is also a lens of payable ore 40 feet in width and 700 feet in length, which has been formed at the expense of red slate country.

The lens is siliceous in character, and passes insensibly both to north and south into a tight quartz lode of no value apparently. The western and eastern country of the lens consists of red slate, so also does the eastern country, nevertheless, the lens ends north and south in sandstones, siliceous slates, and sandy slates, the values not continuing beyond the influence of the slates. Numerous subparallel and subsidiary fissures are associated with the main lode. These quartz veins in the eastern sandstone appear to be of no value. The payable lens is worked for gold. Copper and galena values are also present.

The Fort Bourke lode to the north occurs in an area traversed by parallel fissures in crushed country. Sandstone forms its eastern wall. The Freehold, East Cobar, and the Tharsis veins belong to the same crushed line. These, however, have not yielded payable results up to the present.

The Gladstone is another example of a compound fissure traversing slates and containing copper. Although not in actual line with the Great Cobar, it is genetically associated with it.

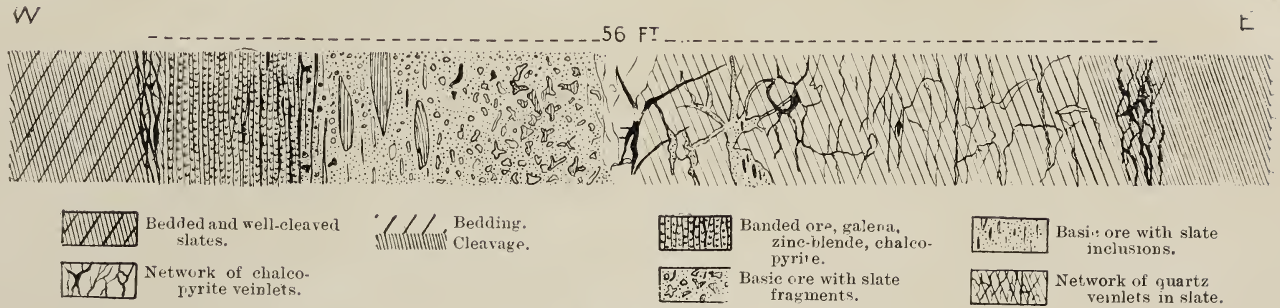

Fig. 1.

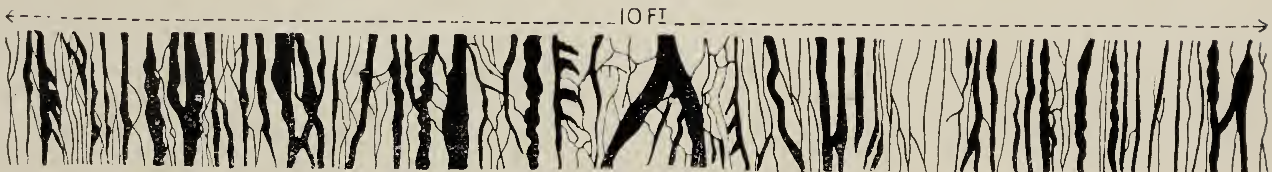

Fig. 2. Sketch Sections across Great Cobar Ore Bodies.

Upper Figure.—General section across lode based upon measurements secured in Northern Lens, No. 9 level. Ore body is roughly divisible into two portions, a western basic mass and an eastern acid mass, separated by belt of quartz veins, lean ore, and slate. Western wall of well-cleaved and bedded slate. Eastern country altered by introduction of silica, and wall not at all well-defined.

Lower Figure.—Detail of acid eastern ore body in northern portion of chamber on twelfth level (1,250 feet). Network of veinlets of chalcopyrite, pyrrhotite, and magnetite in altered slate. Basic mineral percentage about 40 per cent.; balance slate.

The Great Cobar and the C.S.A. ore bodies are examples of large local replacements of slates along definite lines. The replacement bodies alone appear to be payable, their continuations north and south as definite veins not having been found to be payable up to the present. Neither do any of the subsidiary parallel fissures to the east appear to be payable.

The C.S.A. outcrop is large and somewhat boat-shaped, being about 300 feet in width and of about the same length. The country associated with it is of contorted and steeply dipping claystones. The Tinto lens appears to lie on the same compound fissure as that of the C.S.A.

The replacement action along the Great Cobar has resulted in the development of three lenses of ore separated by numerous stringers and veins of quartz in slate. The lode and lenses are vertical, and the pitch of the lenses is steep to the north.

Genesis of the Ores.

The question as to the origin of the ores of the Cobar District may be discussed under several heads, namely :—

(1) Genesis of the ore channels.
(2) Genesis of the primary ores.
(3) Genesis of the secondary ores.

(1) *Genesis of the Ore Channels.*—The field evidence strongly suggests that a faulting action caused the formation of the Cobar fissures. The faulting was peculiar, in that local intensity of action (or movement) continually changed its position. As one follows a line of lode in a north-north-west direction, the main plane of weakness may be observed to decrease in intensity.

Parallel and subparallel shattering of the country over fairly wide zones is also noticeable. The perfect cleavage of the associated slates is parallel to the main planes of movement, while it is less prominent in the sandstones, quartzites, claystones, and shales at moderate distances from the lodes.*

Other evidences of faulting action have been supplied upon pages 68–75.

At Nymagee and Shuttleton additional evidence of the origin of the lodes was obtained.

The Nymagee, Shuttleton, and Mount Hope lodes occur in sediments† almost indistinguishable from the Cobar sandstones and slates, and notably at Mount Hope the lode appears to lie in a plane of faulting.

It is probable that the planes now partly exposed at the surface were formed at considerable depths because of the characteristic absence of breccias and other signs of vein-filling materials which are so common in fissures which have been formed nearer the surface. Close examination of the ore deposits as exposed along the various mine workings, both in hand specimens, under a strong lens and under the microscope, shows that the ore is frequently banded, and that the bands alternate with small lenticular patches of slate which have undergone partial assimilation by the pyrrhotite and chalcopyrite (Plate 21). In other specimens the sulphides and the silica or impure quartz appear to form

* A similar case of faulting at the Balfour Field, Tasmania, has been mentioned to the Writer by Mr. L. K. Ward, B.A., B.E., Government Geologist of South Australia.
† See also Mr. J. E. Carne, "Copper-mining Industry," pp. 213, 251, and 256.

a cement to the fragments of a slate breccia. This brecciation is only apparent, however, and represents a double process—one, the development of great numbers of interlacing cracks by the shearing action; and one the introduction along these cracks of silica and sulphides in solution with replacement by these solutions of films or bands of the contiguous country. In this manner the appearance of brecciation is produced. Plate 22 illustrates various phases of alteration which have taken place along No. 9 Level of the Great Cobar Mine.

(2) *The Primary Ores.*—In any discussion as to the origin of the primary ores it is advisable to consider the characteristic mineral association, the petrology, and the physical conditions under which the ores may have been formed.

The association of the ores found below water-level in the Cobar district throws a strong light on the problem of their genesis.

In this connection, Mr. Carne has shown for the Great Cobar Mine that the ores won from the upper levels averaged more than 12 per cent. of copper.* At still greater depths the copper values decreased to 4 per cent. through values of 9, 8, and 7 per cent. The great bulk of the ore won since 1895, namely, almost 2,000,000 tons, has averaged between 2 and 3 per cent. copper. Since Mr. Carne's report of 1908, a large tonnage of ore has been treated, namely, about 1,500,000 tons, the average percentage of copper won being about 2·10. These large tonnages came from workings well below water-level. Above and just below that level the values were always rich, but of fluctuating value. In the lower levels, on the other hand, the average tenor in value of the ore is fairly constant, and both the mineralogical and geological associations are similar. All the chalcocite and the rich masses of chalcopyrite of the upper levels are thus excluded, in this discussion, from the primary ores.

The chalcopyrite of the lower levels occurs as streaks and feathery aggregates in solid pyrrhotite and magnetite, as bright yellow veinlets along slate joints, or as strings and apparent cements in silicified breccias. Associated with these are also masses of galena, zinc-blende, and iron pyrites.

It is the origin of such bodies that is here under consideration.

Relative Ages of the Mineral Groups.—An examination of the minerals of the Queen Bee, Peak, Occidental, Chesney, and Fort Bourke lodes furnishes but a slight clue as to the relative ages of the pyrrhotite-chalcopyrite and the iron pyrite-galena-zinc-blende groups.

At the Peak the veins are either gold-quartz or silver-lead examples, and furnish only negative criteria of the relative ages of the primary ores.

Along the Occidental-Chesney and Fort Bourke lines of lode the chalcopyrite and pyrrhotite occur associated with galena and zinc-blende. The chalcopyrite and pyrrhotite are very similar in appearance to that occurring in the more western group of veins, but the relations of the pyrrhotite with the galena and zinc-blende present were such as to render difficult any determination of their relative age.

In the Great Cobar lode, however, the evidence of relative mineral age is distinct. The chalcopyrite and pyrrhotite (with magnetite) comprise the main mass of the ore bodies, while the pyrite, galena, and zinc-blende are

* "Copper-mining Industry," 1908, p. 243.

confined in the main to a definite vein varying in width from a mere thread up to 11 feet, which occupies the western portion of the lode as worked at present. The separation from the pyrrhotitic body in places is as clean as with a knife.

Both mineral groups occur in the C.S.A. and Tinto Mines, and appear to possess somewhat similar relations as in the Great Cobar lode.

The evidence then points to an earlier introduction of pyrrhotite, magnetite, chalcopyrite, silicate of iron, and silica, and to a later one of silica, iron pyrites, galena, and zinc-blende.

Physical conditions under which minerals were precipitated.—There are two points needing careful consideration in this connection. In the first place, there are the peculiar variations in the mineralogical contents themselves, and in the second place there are the peculiar characters of the lodes themselves.

Mineral association.—Lindgren mentions iron pyrites as a mineral occurring indifferently in the deeper, middle, and upper vein zones—that is, as occurring under conditions either of great heat and pressure or of slight temperature and pressure. Pyrrhotite and magnetite are cited as examples of minerals formed under conditions of great heat and pressure. Galena and zinc-blende occur in regions both of great and negligible pressures. Galena and pyrite also occur as products of sulphide enrichment.* Van Hise in his treatise on metamorphism (pp. 213–216), points out that pyrrhotite may be considered as Fe_5S_6 to $Fe_{15}S_{16}$, chiefly $Fe_{11}S_{12}$, with a specific gravity of from 4·58 to 4·64, while iron pyrites may be considered as FeS_2, with a specific gravity of from 4·95 to 5·10. "The mineral pyrrhotite by recrystallisation passes into pyrite." "The alteration of common pyrrhotite into magnetite . . . may be written as follows:—

$$3\ Fe_{11}S_{12} + 116\ O = 11\ Fe_3O_4 + 36\ SO_2 + k.$$

or

$$3\ Fe_{11}S_{12} + 36\ H_2O + 8\ O = 11\ Fe_3O_4 + 36\ H_2S + k.$$

"In the change of pyrrhotite to magnetite the volume is decreased 24·27 per cent." He also points out (p. 215) that "the change of marcasite to pyrite is an excellent illustration of the principle that where the pressure is great minerals tend to pass into other minerals having a higher degree of symmetry and a higher specific gravity." The author further states that: "Doubtless where the necessary chemical reactions can take place there is a tendency in the lower zone for pyrrhotite to alter to pyrite" (pp. 215–216), and "The conditions for the formation of magnetite from pyrite, marcasite, and pyrrhotite are the presence of some oxygen. . . . but not a sufficient amount to fully oxidise the iron, and considerable pressure. . . . The alterations of the sulphides to magnetite involve a decrease of volume of 24 to 39 per cent. and liberation of heat. Corresponding with this fact, the changes take place in the belt of cementation, or in the zone of anamorphism (p. 216)."

According to the researches of E. T. Allen and others for the Carnegie Institution of Washington, on the sulphides of iron, summarised in the Annual Report of the Director for 1910, pyrite dissociates into sulphur and pyrrhotite above 500° C. [Quoted from communication to Writer by Van Hise in 1911.]

* "Economic Geology," 1907, Vol. II, pp. 113–114 and 123–125.

Van Hise gives other interesting particulars concerning magnetite: "The conditions for the formation of magnetite from pyrite, marcasite, and pyrrhotite are the presence of some oxygen, but not a sufficient amount to fully oxidise the iron, and considerable pressure. Where iron carbonate is present, which also alters to magnetite, oxygen is not necessary. . . . The alterations of the sulphides to magnetite involve a decrease of volume of 24 to 39 per cent. and liberation of heat. Corresponding with this fact, the changes take place in the belt of cementation or in the zone of anamorphism."*

"The alteration† to magnetite is especially characteristic of the zone of anamorphism, but it cannot be asserted not to take place in the belt of cementation."‡

The peculiar association of magnetite with pyrrhotite and Ekmannite in the Cobar lodes will be dealt with later. At the present place it may be sufficient to state that magnetite appears to be formed under conditions of great heat even in the absence of great pressure. Thus magnetite may be formed easily during copper smelting processes. Great heat, however, seems necessary in its production.

Introduction of Minerals.—The next point of interest is the method of entry and precipitation of the minerals. To assist in the description, a number of drawings and photographs of the minerals have been prepared so as to illustrate the theory of replacement here adopted.

It has already been shown that the lodes exhibit very little signs of filling of large open cavities, although the great ore lenses of the field suggest that slip faults have occurred along the main line of weakness and have thereby so shattered the country locally that the mineralised solutions have rapidly replaced the country with the production of ore bodies suggestive, upon first sight, of the filling by ore of open spaces.

It will be advisable to consider the introduction of the ore bodies from two aspects, namely, one in which the general relations of the ore and gangue minerals are considered, and one in which the details of replacement are considered.

In the first place the question of the peculiar association of pyrrhotite, magnetite, chalcopyrite, iron silicate (Ekmannite), and silica in the Great Cobar is considered, also the general absence of pyrrhotite in the Queen Bee, and the association of pyrrhotite and iron pyrites in the Tinto, but with the corresponding absence of magnetite. The question of the association of galena, zinc-blende, and iron pyrites is also considered.

For a considerable time the Great Cobar Mine has been worked upon averages approximately as follows:—Sulphur, 14 per cent.; copper, 2·60 per cent.; iron, 41 per cent.; silica, 16·22 per cent. It will be evident at a glance that there is not enough sulphur present to completely change the whole of the copper and iron to sulphides. On the other hand, it is a well known metallurgical principle that if sulphur be presented to bodies of iron and copper, under conditions favouring the chemical combination of these bases and the sulphur, no iron sulphide is formed until all the copper has been satisfied and converted into some stable form of sulphide. After copper the iron possesses the greatest affinity for sulphur. If silicon, oxygen, sulphur, and iron be brought into association under conditions of great heat or pressure,

* "Metamorphism," 1904, p. 215. † Of siderite.—E.C.A. ‡ *Ibid.* p. 245.

Photo. Govt. Printer.

Brecciated Ore from Queen Bee Mine, 150 feet below Surface.

Cemented with Copper Ore.

or a combination of the two, then the iron shows a greater affinity for the sulphur than for either the silicon or the oxygen. On the other hand, after the iron has utilised all the remaining sulphur in the formation, the balance of the iron will combine with the silicon and the oxygen. The particular forms which the iron silicate and iron oxide will take depends upon the physical conditions obtaining at the time of the chemical combination.

We may assume, then, that silicon, oxygen, sulphur, iron, and copper entered the shattered slate region of Great Cobar, the proportions of the elements being somewhat as those supplied above from the working mine averages. Then, in the first place, as the geology of the district suggests, these elements were associated under conditions of great heat and great pressure—in fact, they formed compounds characteristic of the zone of Anamorphism of Van Hise. The copper would first demand its share of sulphur, and it would combine with the sulphur in the form most consistent with the conditions of great heat and pressure present. In this way a copper sulphide would be formed, and as there still remained a fair balance of sulphur, this would combine with some of the iron. The iron could combine with the sulphur to form either pyrrhotite (magnetic pyrites) or iron pyrites, but, as the iron was greatly in excess of the sulphur, there would be a tendency to economise the sulphur, on account of the great affinity of iron for sulphur. Under ordinary chemical conditions, with slight heat and pressure, however, pyrrhotite cannot form; while, on the other hand, under conditions of great heat and pressure pyrrhotite may easily be formed, and this, then, would be the form adopted by the iron sulphide at the great depths at which the Great Cobar lode was formed. The copper occurs in the form of chalcopyrite, a mineral with a formula which may be written—[$Cu_2S + Fe_2S_3$] or [2 $CuFeS_2$]. In this mineral it will be seen that the sulphur has been much economised.

But with such a high percentage of iron present as 41, and such a low percentage as 14 of sulphur, it is evident that even with the economy of sulphur exercised in the formation of Fe_7S_8, instead of FeS_2, that there would still be a great proportion of iron which could not combine with sulphur, inasmuch as the atomic weights of sulphur and iron are about 32 and 56, respectively.

It is then necessary to ascertain what would be the nature of the combinations which the balance of the iron will form with any other elements present, such as oxygen, silicon, or aluminium.

As an introduction to this, it may be advisable to quote one or two authoritative statements concerning chemical reactions under conditions of variable heat and pressure. Thus, to quote from Van Hise in "Metamorphism," 1904, p. 107:—

> "A more general statement of the law as to the relations of heat and chemical reactions is that of van 't Hoff:—'On the whole, the preponderating chemical reactions at lower temperatures are the combinings (associations) which take place with a development of heat, while the reactions preponderating at higher temperatures are the cleavings (dissociations) which take place with the absorption of heat.'* The meaning of this law may be illustrated by the following reactions:—At ordinary temperatures CO combines with O, producing CO_2, with great liberation of heat; at very high temperatures CO_2 dissociates into CO and O with very great absorption of heat."

* Quoted from Nernst, "Theoretical Chemistry," London, 1895, p. 583.

"Another illustration of the very important way in which increase of temperature increases chemical action is the increased activity of substances which at low temperatures are relatively inert. While at ordinary temperatures carbon dioxide replaces silica in silicates, at temperatures of 100° C. silica, if present in abundance, may replace carbon dioxide in carbonates."*

Van Hise then proceeds to show (p. 110) that, notwithstanding this law of absorption of heat in regions of great depth (pressure) in the earth's crust, the increase of heat with depth is very great, and that therefore his zone of anamorphism† is typically one in which chemical reactions take place under conditions both of great heat and pressure.

"The very important reactions in the zone of anamorphism are silication, or union of silicic acids with bases producing silicates, and dehydration. Deoxidation is subordinate."‡

"Whether or not pressure in the zone of anamorphism is sufficient to deoxidise compounds is uncertain. Certain it cannot be asserted that the pressure is sufficient to squeeze out a part of the oxygen of hæmatite, thus converting it to magnetite."§

Van Hise also shows that the heavier silicates should begin to develop in the deeper portions of the zone of anamorphism, the quartz, mica, and other lighter silicates passing into such minerals as garnet, andalusite, staurolite, and sillimanite.

Conformably with these recognised laws of physical chemistry, it is to be expected that the balance of the iron, left over after the formation of the iron and copper sulphides in the Great Cobar lode, would combine with the silicon and oxygen present, and that the peculiar silicates and oxides formed would be anhydrous. For it has been shown already that pyrrhotite is not known to form under a temperature less than 500° C., and any mineral associates of pyrrhotite in the unaltered zone must have been subjected to the same great heat as that experienced by the pyrrhotite.

We would thus expect to find magnetite or hæmatite formed, as also silicates of iron. In the case of the Cobar lode magnetite was formed and not hæmatite. This may be by analogy with the known formation of iron silicates and magnetite during copper-smelting under certain conditions (such, for example, as the introduction of certain basic silicates into the charge instead of free quartz).

The limitations of the amount of heat and pressure present during the formation of the Great Cobar lode are well shown by the mineral paragenesis. With a group of elements such as oxygen, silicon, iron, copper, and aluminium reacting upon each other under conditions of enormous heat and pressure, the tendency would be to form the usual copper and iron sulphides and the heavier silicates. We would thus expect to have the following minerals:—Chalcopyrite, pyrrhotite, magnetite, hæmatite, iron silicate, sillimanite, andalusite, staurolite, garnet, cyanite, corundum, and allied minerals. But the absence of such minerals as garnet, cyanite, sillimanite, and staurolite suggests that the Great Cobar lode was formed in the upper or middle rather than in the lower portion of the zone of anamorphism.

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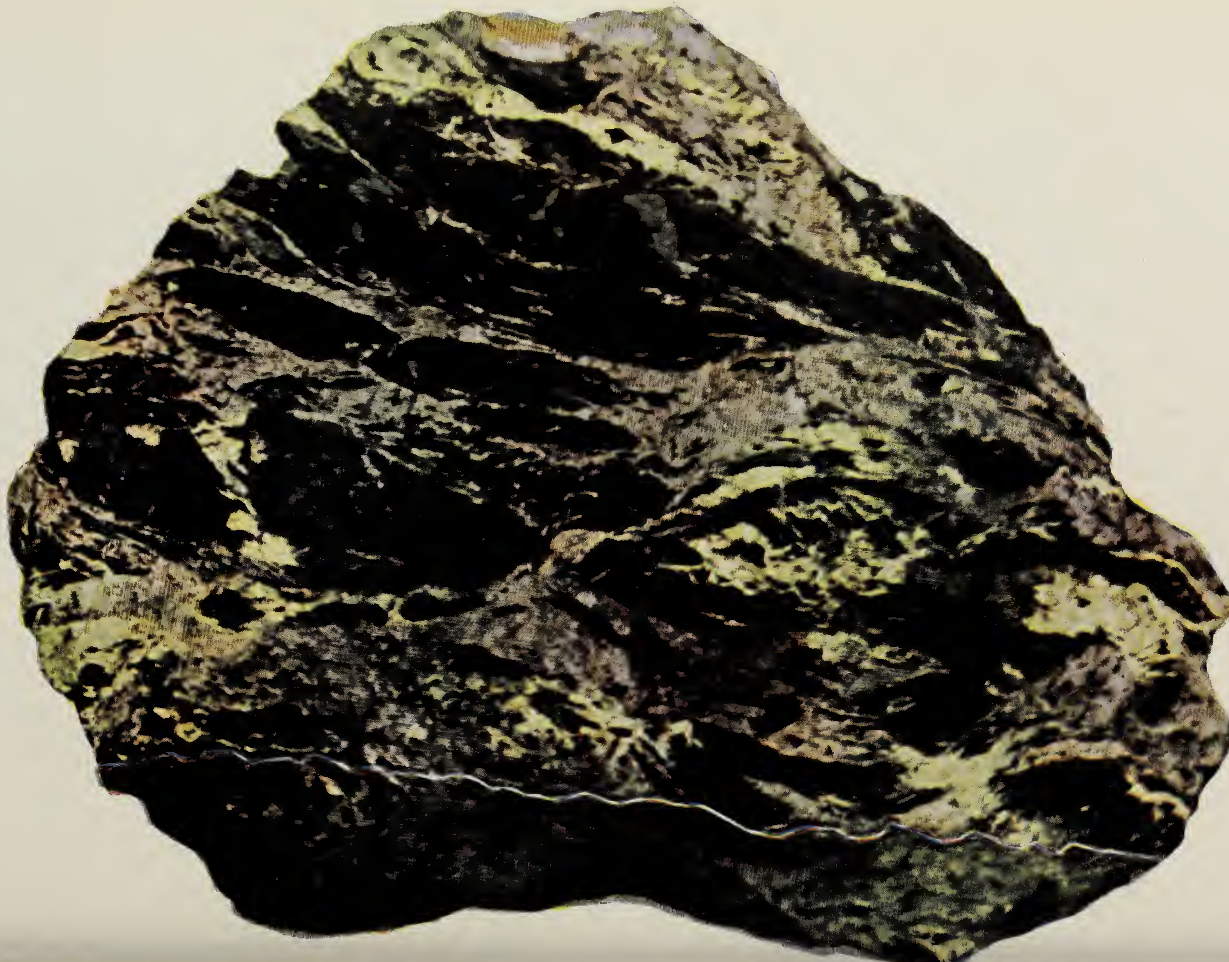
* Van Hise, "Metamorphism," p. 108. Quoted from Gustav Bischof, "Elements of Chemical and Physical Geology," 1854. † The zone of anamorphism may be defined as the zone in which the alterations of rocks result in the production of complex compounds from more simple ones.—Van Hise, *cit.* p. 43. ‡ Van Hise, *cit.* p. 168. § Van Hise, *cit.* p. 169.

PLATE XXIV.



With regard to the association of iron pyrites, pyrrhotite, chalcopyrite, and the general absence of magnetite in the Tinto Mine, it can only be suggested that in this mine there was a greater proportion of sulphur present with respect to the iron than in the Great Cobar.

It is now necessary to glance briefly at the second group of primary minerals, namely, iron pyrites, marcasite, galena, zinc-blende, calcite, and iron carbonate. The geological associations are such as to indicate a much younger age for these minerals than the pyrrhotite–magnetite–Ekmannite group in that they appear to cut across the older mineral groups, and that they are generally associated with zones of crushed and uncemented structures, whereas the older masses have been tightly cemented into the slate country by silicification. The galena and zinc-blende might readily be expected to form at any depth below the earth's surface, but the calcite, the marcasite, the iron pyrites, and the crushed and uncemented nature of the country suggest formation at very moderate depths only.

The next point presented for consideration is the method of entry and replacement of country adopted by the elements.

Silica appears to have been the first mineral to be introduced along the zones of weakness in the area; indeed, the introduction of this mineral seems to have proceeded almost uninterruptedly during the periods of ore deposition. The greatest shattering had taken place in the slates at and near their junction with other slates or argillaceous sandstones. The slates were crushed in a relatively great degree, and therefore presented little difficulty to permeation by mobile solutions,* such as would exist at the depths under consideration. The silica appears to have worked through the slates in networks of strings rather than in definite veins. (Examples: Great Cobar and Cobar Gold Mines.) In the harder rocks, such as the sandstones, the formation of more typical quartz veins occurs; but in these rocks also the introduction of silica along tiny veins was pronounced. (Fig. 15.) Sandstones were often changed to quartzites by such action, and local silicification of slate occurred with the production of impure silica at the expense of the slate. Pseudo-breccias also resulted both as a result of silicification and of still later introduction of magnetic and copper pyrites. The action of this silica was to weld together the shattered sandstones and slates.

Certain specimens suggest a simultaneous deposition of chalcopyrite and pyrrhotite (Plate 24), while the pyrrhotite in certain specimens appears to form tiny streaks through the chalcopyrite; while at other times the chalcopyrite appears to have been formed at the expense of the pyrrhotite (Plate 26).

Plate 24 illustrates another association of pyrrhotite, chalcopyrite, and slate found in the Tinto Mine, 7 miles N.N.W. of Cobar.

Here a structure is shown which throws light on the origin of the pseudo-breccias of the Cobar lode.

In Plate 21, Fig. 1, the slate is seen to have been shattered either along its bedding or its cleavage planes. Pyrrhotite has found its way along these lines of weakness, and has partially assimilated the slate. This stage is seen to be one in advance of Plate 24. A common method of introduction of the pyrrhotite into the silicified slate is as small tabular hexagonal crystals.

* Water above 90° C. is five times as mobile as water just above freezing. —Van Hise, "Metamorphism," *cit.* p. 141.

Plate 25 illustrates a much more advanced stage of slate assimilation by pyrrhotite (and associated chalcopyrite). The specimen from which the sketch is taken occurs in close proximity to that from which Plate 21 was secured. The slate can no longer be recognised as such, but has a sooty or carbonaceous appearance, with irregular outlines. Pyrrhotite and chalcopyrite may be seen eating into the mass as grains and small, irregular strings, all developed at the expense of once unaltered and continuous slate.

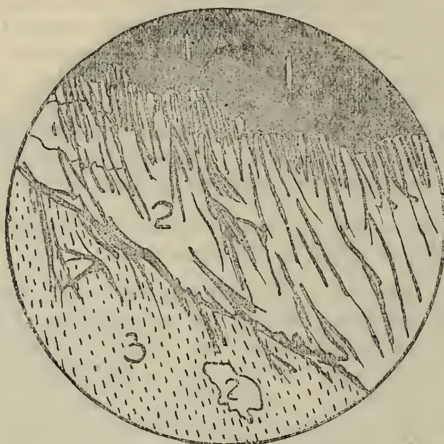


Fig. 11a.

Association of magnetite, pyrrhotite, and iron-silicate (?) in Great Cobar Mine, No. 10 Level. x 30 diameters.

1. Magnetite.
2. Chalcopyrite.
3. Pyrrhotite.

The black threads and lines are probably silicate of iron.

Magnetite as grains formed simultaneously with the chalcopyrite and pyrrhotite, although from its general massive occurrence nearer the peripheral portions of the ore bodies it would appear to slightly post-date the general entry of the sulphides. See, however, Plate 26.

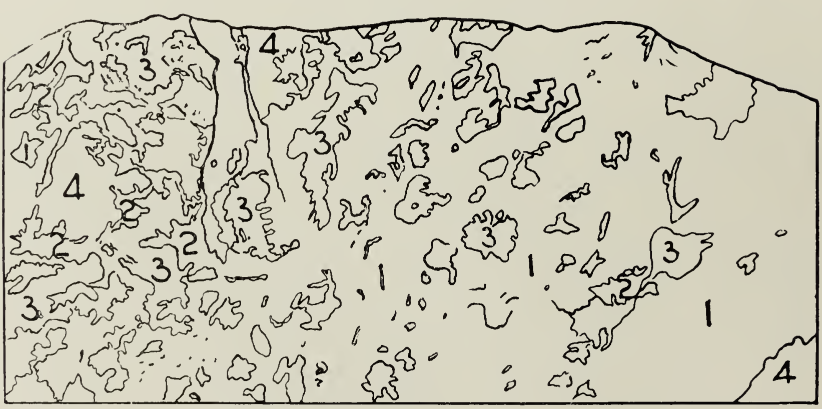
Strings and most delicate networks and feathery patterns of chalcopyrite may be seen forming through both the altered slate and the associated pyrrhotite. In hand specimens also tiny crystals of chalcopyrite may be seen in the siliceous slate, impure silica, or pyrrhotite. Under a strong lens, however, it may be seen that these apparently disconnected grains in hand specimens are in reality connected by tiny veinlets of chalcopyrite.

This is shown in Plate 25, Fig. 1, taken from a specimen of quartz from the Cobar Mine. In this case the impure quartz appears to have arisen as the alteration of slate.

A most interesting point in this connection is the occurrence of a very large mass of banded chalcopyrite and pyrrhotite forming the eastern portion of the northern lens on the No. 10 level of the Great Cobar Mine. At this spot the slate has been replaced along its bedding planes. The strike is locally about N. 30° E., and suggests the replacement of country along a

1. Silicified slate and impure silica.
2. Impure silica.
3. Silicified slate.
4. Chalcopyrite.

Slate is altered to impure silica, and the still later chalcopyrite patches here shown are connected by microscopic crystalline forms like threads of beads.

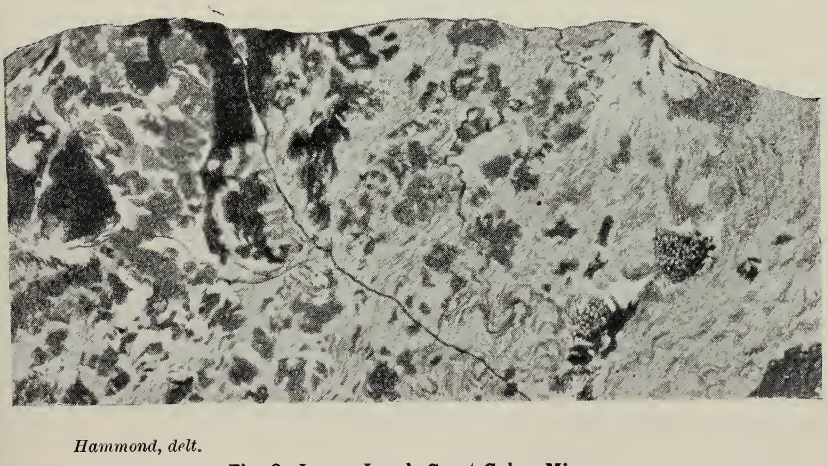


Pyrrhotite and chalcopyrite in altered slate. Under microscope pyrrhotite shows characteristic tabular forms.

1. Pyrrhotite and altered slate with small crystals of chalcopyrite.
2. Chalcopyrite.
3. Altered slate with crystals and threads of chalcopyrite and chalcopyrite.
4. Altered slate.

P. T. Hammond, delt.

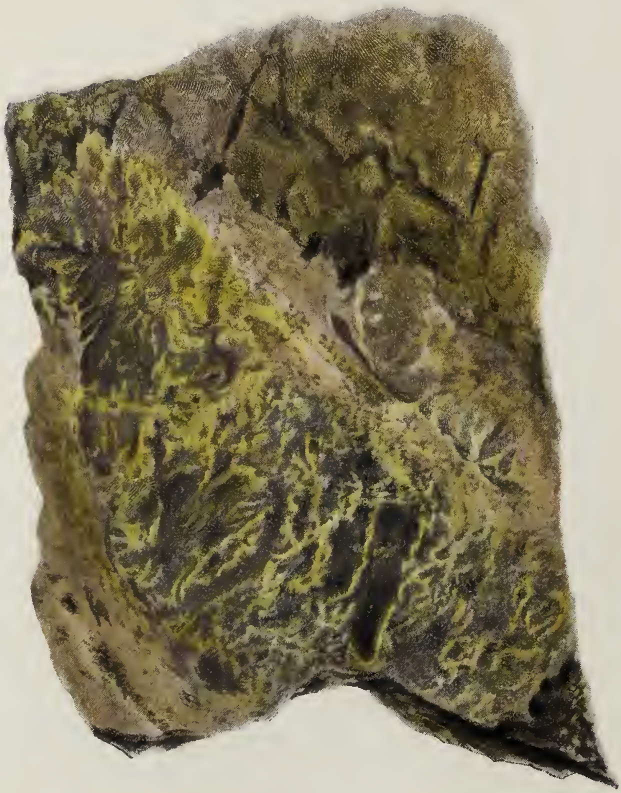
Fig. 1. Siliceous Ore, Great Cobar Mine X2.



Hammond, delt.

Fig. 2. Lower Level, Great Cobar Mine.

PLATE XXVI.



P. T. Hammond, delt.

Association of Pyrrhotite, Magnetite and Chalcopyrite in Great Cobar Mine, No. 9 Level, Northern Lens.

2. Magnetite.
3. Pyrrhotite (magnetic pyrites).
4. Pyrrhotite with threads of lenses of chalcopyrite.
5. Chalcopyrite veinlets.

crumple or fault in the rocks. Similar magnificent replacements analogous to fahlbands form the eastern portions of the ore bodies between the tenth and twelfth levels. (Plate 22 and Fig. 12.)

Figs. 36 and 37 in Finlayson's* report on the Huelva deposits, are strikingly suggestive of Cobar types.

Iron pyrites occurs massive, as grains and in crystalline form. In some mines it has replaced impure quartz, until the silica has been left as grains in the centre of a mass of pyrites. Nodular pyrites has also been formed along the western wall of the Great Cobar. The action of the iron pyrites, however, has not been to weld the country together. In this respect it stands in marked contrast to the action of the earlier silica, pyrrhotite, and chalcopyrite.

In certain mines galena and zinc-blende made their entry practically contemporaneously with the iron pyrites. It is not certain which of the two sulphides was the first to effect an entry. Both the zinc-blende and the galena may be seen developed as strings through all other associated minerals. (Plate 27.)

The zinc-blende is massive, and is spread through the surrounding sulphides and country as small feathery aggregates or irregular bunches of fine texture. Its method of occurrence is highly suggestive of the replacement of the associated rocks. The galena occurs as veinlets, strings, feathery aggregates, and small lenticular patches, dying out on all sides into the associated sulphides and country, and thus apparently not connected with other masses. A banded appearance is often noticeable in the galena and zinc-blende masses. Plates 22 and 27 illustrate the occurrence of these minerals.

Under a strong lens or a microscope, these galena aggregates may be seen to be connected by tiny grains of the same material, somewhat like beads threaded on to a string. In the Cobar Gold lode the galena winds in and out of the auriferous quartz in an apparently haphazard fashion, and is not confined to one side of the lode as it is in the Great Cobar Mine. It is, however, of later origin here than the associated minerals. In the C.S.A. Mine a galena vein has cut through a copper lode, and the evidence may thus be generally accepted for the relative youth of the galena and associated zinc-blende, as compared with the pyrrhotite bodies.

The peculiar occurrence of the galena and zinc-blende, as shown in the accompanying figures, shows that it has been developed at the expense of the surrounding minerals.

Ore Lenses.—It will be advisable at this stage to discuss the formation of the ore lenses themselves. The principal examples of such lenticular bodies of ore occur at the C.S.A., Great Cobar, Cobar Gold, Chesney, Occidental, and Queen Bee Mines. It is a matter of observation that these lenses occur in relatively soft red slates, well jointed and crushed, and that the more typical quartz veins are to be found in the associated sandstones, or in coarser, harder, and more siliceous slate types. The ore bodies of the Tinto, C.S.A., and Great Cobar Mines may be classed as basic, while those of the Cobar Gold, Chesney, Occidental, Peak, and Queen Bee Mines are of acid nature. The basicity of the former group is due to the abundant presence of pyritic gangue, the acidity of the latter group to an abundance of silica.

The members of the first group occur in slates and claystones, while those of the second group occur at the contacts of heavy sandstones and red slates.

* "Economic Geology," Vol. V, 1910, pp. 403-437.

The softer slates have been more crushed and sheeted than the associated sandstones, and it is thus highly probable that minor faults have been superimposed upon the main plane of dislocation, with a tendency to produce cavities here and there. Large cavities, under the enormous pressure experienced, would be closed almost simultaneously with their formation.

The mobile silica and sulphides rose most vigorously along the major planes of dislocation, and spread thence more easily through the crushed zone than through the less crushed sandstones and denser slates. The mobility of the deep-seated solutions also allowed of ready entry along microscopic joints. (Plate 28.) The texture of the soft slates also, all other things being equal, allowed of their readier replacement than of the denser and coarser varieties of rock. This is well exemplified at the Cobar Gold Mine, where the siliceous slates and sandstones cut off the lens to the north and south, the lens itself being confined to the softer red slates of the intermediate area.

After this earlier period of lode formation a revival of movement along the old zones of weakness occurred. Thus, at the Great Cobar Mine, the main lode slipped on itself along its western wall. The result was, in the first place, a crushing of the country, with the production of much crushed slate. The lode is much weakened along this side, and mining operations, in certain stopes, have to be conducted with great care, owing to the presence of these products of crushing. Replacements of country by galena, zinc-blende, iron pyrites, and some copper pyrites have taken place along this portion of the lode.

Sources of the Ores.—From the evidence already supplied, it is highly probable that the Cobar lodes have resulted from the more or less complete replacement of country by iron, copper, lead, zinc, and silicon. The problem of the earlier history of the ore bodies still remains to be considered.

In this connection the almost complete absence of igneous rocks in the Cobar district is most significant. With the exception of the two tiny "pipes" lying about 14 miles to the south-east of Cobar, the area mapped during the present survey reveals no sign of igneous intrusions. The whole of the County of Robinson, an area exceeding 2,000 square miles, contains no igneous rocks other than those mentioned. Furthermore, the rocks of this large area are all of greater age than the igneous types, and thus there is no chance of such igneous rocks being buried under a younger rock series.

The widespread absence of igneous rocks is all the more significant because the surface now exposed has resulted from the wearing down of a great mountain range (as suggested by an examination of the general section and Main Map). Had igneous rocks existed in mass in the core of such a mountain range it might reasonably have been expected that the great denudation to which such mountain range has been subjected in past Devonian time would have revealed their presence.

It must not be forgotten, however, that a considerable development of igneous rocks occurs eastwards and southwards of the area included in the present survey. Thus a belt of felspar porphyry, about 1 mile in width and 10 miles in length, stretches from Florida (30 miles east of Cobar) to the south. At Nymagee granites occur, and to the west of Nymagee a long line of porphyry stretches north and south for a distance exceeding 50 miles. Similarly for the Mount Hope, Shuttleton, and Wirlong porphyries.

With these porphyries numerous copper and gold mines are in close association, such as the Wirlong, Shuttleton, Mount Hope, and Bobadah Mines. It is possible that these great dyke-like masses of porphyry may have been instrumental in setting up a vigorous circulation of heated waters containing copper, gold, silver, lead, zinc, iron, sulphur, and silica in solution.

1. Chalcopyrite.
2. Pyrrhotite (magnetic pyrites).
3. Galena.
4. Altered slate with pyrrhotite.
5. Altered slate.

1. Chalcopyrite being replaced by zinc and galena.
2. Intimate mixture chalcopyrite, zinc-blende, and galena.
3. Galena.

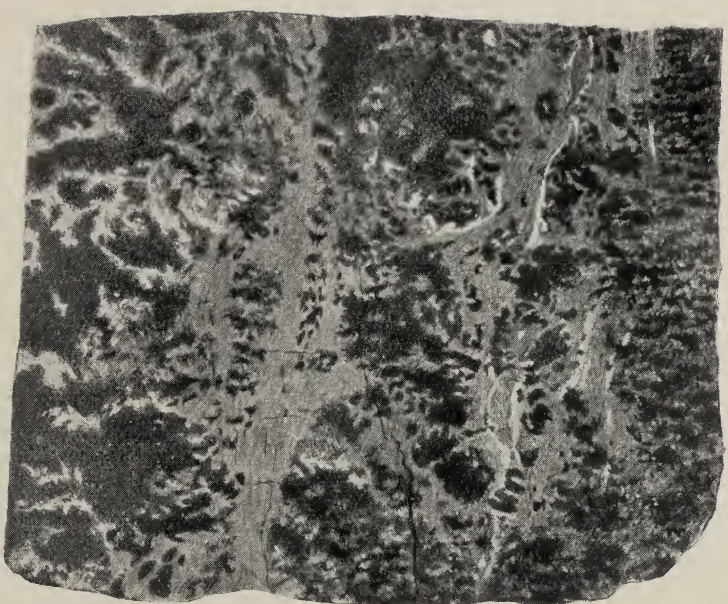
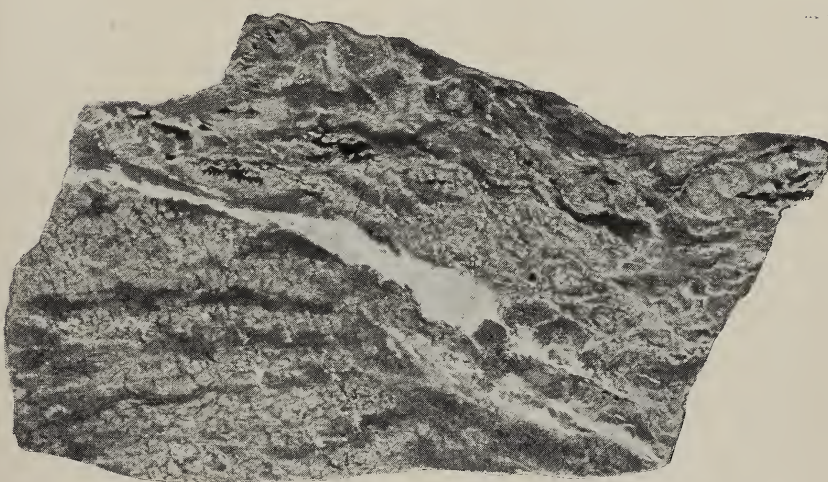


Fig. 1. Western Wall, Northern Lens, No. 9 Level, Great Cobar Mine.



P. T. Hammond, delt.

Fig. 2. Western Wall, Northern Lens, No. 9 Level, Great Cobar Mine.

PLATE XXVIII.

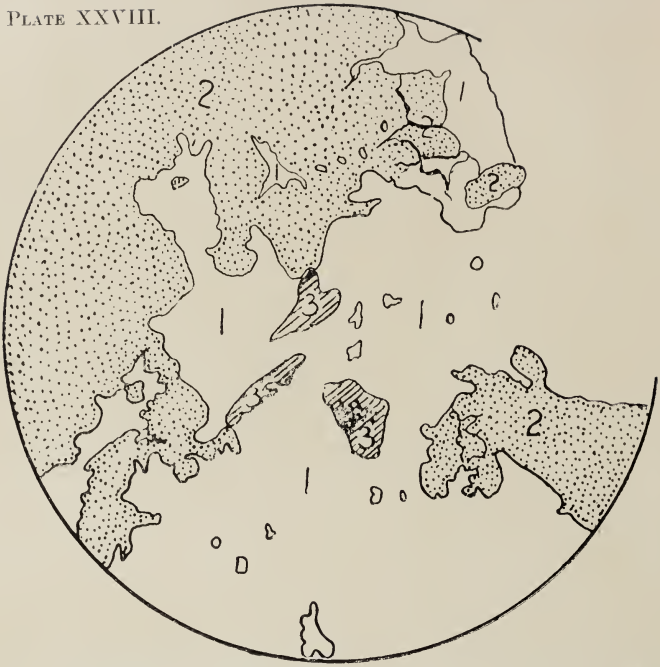


Fig. 1. Replacement of Slate by Quartz and Pyrrhotite, Great Cobar Mine.
x 30 diameter.

1. Pyrrhotite.
2. Quartz.
3. Impure silica with quartz and pyrrhotite.

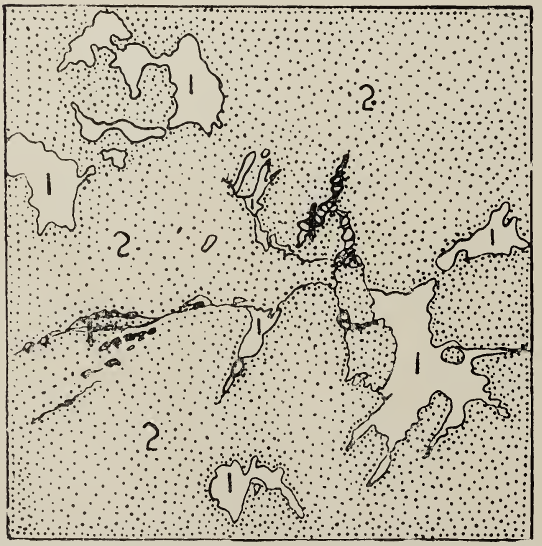


Fig. 2. Development of Pyrrhotite in Quartz, Great Cobar Mine.
x 30 diameter.

1. Pyrrhotite, threads also of small thick crystals shown as black figures.
2. Quartz (stippled areas).

This point may be more definitely settled when the survey of the Cobar district has been extended farther to the east and south. There is no apparent reason, however, for calling in the assistance of a body as distant as the Canbelego and Nymagee porphyries to explain the presence of the Cobar lodes.

In the second place it is almost certain that by whatever action it was produced the old mountain range was dislocated, relief of pressure being obtained by faulting in parallel zones, the intensity of such faulting action appearing to pass somewhat *en echelon* from Mount Hope and Nymagee to the C.S.A. by way of the Bee, the Peak, and Cobar. The force producing the lodes is manifest over a distance exceeding 100 miles in length, and the principles of mechanics thus suggest that its origin was deeply seated. The general field evidence also supports this contention. The zones of strain, therefore, along which the lodes have been developed may be conceived as continuing downwards to great depths far below the zone where large actual fissures could exist.*

Along these zones of strain, mobile solutions would be enabled to find their way towards the surface. In other words, the great movement in the Cobar district which exhibited itself as faulting or shearing at and somewhat near the surface was expressed as a release of pressure at depths where the heat and the original pressure had been enormous, and this would allow the escape of heated material as solutions which had been hitherto unable to ascend either by reason of the impervious mass of sediments, and other rock types above them or even to reveal their true nature as solutions by reason of the pressure exerted by the overlying rocks, the solutions only coming into being by reason of the rock flowage caused by the relief of pressure at the lower points of the zones of dislocation or movement. Such solutions in their entirety may easily be conceived as having been derived from a deeply-buried geological complex, and as having been subject to later concentration along the great planes of dislocation and shearing under consideration.

The introduction of the later iron pyrites, galena, zinc-blende, silver, and copper pyrites may be explained by a deeply-seated intrusion which occasioned both a rejuvenescence of movement along the old fault planes and a complete change in the character of the ore entries.

It is almost certain that the ores cannot have been derived by a process of leaching from the surrounding rocks, for it is difficult to explain in this way the close association of ore masses of varying age and of quite dissimilar types. That is to say, if masses of silica, chalcopyrite, pyrrhotite, and magnetite be assumed as having been segregated from the associated slates, sandstones, conglomerates, quartzites, and shales, how could the same rocks be expected to yield masses of galena, zinc-blende, and iron pyrites at a later date when such rocks had not received any addition to their contents from outside sources such as an intrusion into them of igneous rocks?

It will be seen that neither the views of those who derive ore deposits by leaching processes from the associated rocks nor of those who derive all ore deposits directly from igneous rocks appear to account for the Cobar deposits. On the other hand, the ore deposits appear to have been derived from rocks situated at great depths, at depths where rocks became plastic upon release of pressure. Igneous rocks doubtless rose towards the surface as a result of this relief of pressure. The Canbelego-Nymagee porphyries and the Queen Bee porphyries probably originated in this way.

* Van Hise ("Metamorphism," 1904, pp. 189-190) calculates that the depth at which rocks tend to flow and fill all spaces is less than 10,000 or 12,000 metres below the surface. Adams, however (Journal Geology, 1912, p. 97), suggests that these figures of Van Hise need modification.

(3) *Secondary Ores.*—These may be divided into oxidised ores and the secondary sulphides. The first group includes limonite, lead gossan, carbonate of lead, chloride of silver, cuprite, malachite, azurite, native gold, silver, and possibly also native bismuth.

The Oxidised Ores—Gossans.—The gossans may be distinguished as true gossans and siliceous gossans. The C.S.A., the Tinto, the Great Silver Peak, and the Great Cobar outcrops are examples in part of true gossans, while the upper portions of the Fort Bourke and the Chesney–Occidental lodes may be taken as types of the siliceous gossans. The depths to which the gossans descend vary from 200 to 420 feet, being practically continuous to water-level. The oxidised ores of copper generally occur in its lower portions, but the free gold values were possibly better in the upper portion of the gossan. The lead gossans of the C.S.A. and of the Great Silver Peak are brick-red to dark red in colour. In places this gossan may be of rich velvety and blackish-brown colour, containing carbonate of lead crystals, and at times showing nests and scattered crystals of chloride of silver. The gold and copper gossans are usually of much lighter colour than the gossans of the silver-lead mines.

The outcrop of a Cobar lode is not always a safe guide to the amount of oxidised iron below. The appearance of the Great Cobar outcrops was deceptive in this connection, and not at all indicative of the large masses of iron and copper found at moderate depths from the surface. In this case it is probable that only the upper and more insignificant portions of the lenses had been removed by denudation.

In the C.S.A. Mine the lower limit of the gossan was well defined. It persisted from the surface to a depth of about 400 feet. Its lower limit was irregular in shape, and showed variations of as much as 30 feet in vertical extent within extremely short horizontal distances. Below it a large boat-shaped mass of carbonate of lead was discovered, which in turn was cut off at or very near water-level by sulphides. Gossan was mixed also with the carbonate of lead in places.

In the adjoining Tinto Mine the gossan is succeeded below by rich masses of chalcocite, which also exhibited the same rapid vertical variations as the lead of the C.S.A. The chalcocite is generally marked off sharply from the gossan, a thin layer of earth occurring between the two. The values of gold and silver in this layer, strange to say, are reported to have been almost negligible.

The general character of the gossan and its peculiar relation to the oxidised ores and to the zone of permanent saturation leave no doubt that at one time the sulphide lodes occupied the positions of the present gossans, and extended thence upwards and beyond the present surface limits. As the mountains containing them were worn down by the action of weathering and streams, so portions of the metalliferous contents appear to have been dissolved and deposited in part in the upper portions of the undenuded lode. During this process the sulphides of iron became desulphurised and oxidised to form the limonite of the gossan.

Copper, Lead, Gold, and Silver Ores.—It has already been shown that the oxidised ores of Cobar have been derived from iron, copper, and lead sulphides, and a general account of the chemical reactions resulting in the formation of these minerals may be found in treatises such as those of Van Hise on "Metamorphism" (pp. 1158–1159), and of Clarke on the "Data of Geochemistry."*

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* U.S.G.S. Bulletin No. 330, pp. 564–572.

Zone of Enriched Sulphides.—The galena and chalcopyrite appear to belong in part to secondary agencies, while the chalcocite of the whole district has every appearance of being due entirely to secondary agencies. In the Great Cobar lode enormous patches of rich chalcopyrite occurred at and near water-level. The mass of the chalcocite appeared to be situated somewhat above that of the chalcopyrite, as already discussed in the earlier pages of the report. In the Tinto, the Gladstone, the Bee, and other mines the rich sulphides near water-level were composed in the main of chalcocite. The chalcocite is intimately associated with the water-level; it is never found much above it, and it never occurs at any but moderate distances below it. The chalcopyrite appears both above and below the water-level to all depths, nevertheless the rich bunches occur near that level and it shows a marked decrease in value at the deeper levels. The chalcocite appears to have replaced both the pyrrhotite (and associated chalcopyrite) and the secondary chalcopyrite in places. Specimens of ore show whole masses of chalcocite absolutely studded with tiny kernels of chalcopyrite resulting from imperfect replacement of the yellow ore by the richer sulphide. The secondary copper pyrites appears to have formed at the expense of the cupriferous pyrrhotite in the upper levels by descending waters and to have gradually decreased in value until it passed into the primary ore.

The peculiar occurrence of galena in some of the levels in the Great Cobar Mine is such as to suggest its formation by secondary action. It occurs as a finely-textured mineral, traversing all the associated minerals in small veins. Generally, however, the galena may be considered as a primary ore. The zinc sulphide appears to be secondary in part, especially in the levels just below water-level.

Analyses of some of the mine waters are supplied in the descriptions of individual mines. In most of these, a surprisingly small copper content is observable. Free sulphuric acid is fairly common throughout the mines. Carbonic acid is not plentiful; soda is fairly common; but potash is almost absent. Chlorides also are common. One would thus expect to find an abundance of chalcocite and chalcopyrite, carbonates, oxides, and native metals, and a general absence of arsenical compounds. This is practically what is found in the mines of this district. The most striking exception is the apparent absence of zinc carbonate (calamine) in the mines of the district. Calamine may occur at Cobar, but has not come under the notice of the present Writer.

Topographical and Climatic Influence.—The country around Cobar is a plain of erosion, and the climate is sub-arid. Water-level is found at depths varying from 200 to 450 feet. The conditions of the wandering water have doubtless not been altered during a long period. Thus there has been opportunity for the formation of rich and large masses of oxidised and secondary sulphide ores above, at, and near water-level.

Broken Hill presents a somewhat similar association of magnificent masses of secondary ore, both of oxidised and sulphide varieties.*

On the other hand, a different condition of things appears to obtain in the wild, mountainous and well-watered country farther to the east. Thus, at Lobb's Hole, Yarrangobilly, near Kiandra, a copper lode crosses the bed of a deep cañon. It outcrops in places in the river bed as a solid copper sulphide [chalcopyrite]. At Drake, water-level was encountered at slight depths from the surface, and rich sulphides, with cuprite and native copper, were obtained at and just below water-level.

* J. B. Jaquet, "Geology of the Broken Hill Lode," Memoirs Geol. Survey N.S. Wales, No. 5, pp. 72 73, 75-85.

Summary of Genesis.— A great mountain range was produced in the Cobar area by a movement of compression. Great fault or shear planes were produced by this action. The influence of these zones of shear or faulting extended to depths at which the rocks were under enormous pressure. By the relief of pressure thus afforded to these underlying rocks, solutions of iron and copper sulphides, and of silica, rose along the planes of dislocation towards the surface, and were precipitated along the fault planes, or, rather, in the parallel zones of slate shattering or movement.

The sulphides do not appear to have been deposited in large open spaces, but as replacements of the slate and sandstone country. The slate country was more easily replaced than the sandstone. Pyrrhotite, magnetite, chalcopyrite, and a curious silicate of iron were the characteristic minerals formed.

A rejuvenescence of the faulting movement permitted the ascent of a completely different group of sulphides, namely, iron, lead, and zinc bisulphides. Pyrrhotite and magnetite are absent from these later deposits.

The old mountain range was slowly worn away to a plain, whose surface was apparently not much above sea-level. The final stages in the formation of the plain were carried out excessively slowly, because at such stage the denudation of a land surface proceeds mainly by weathering and sluggish transportation, and not by strong stream action; moreover, the climate in recent geological time has also become semi-arid, and the streams cannot keep their channels open. Water-level lies at a considerable depth below the present surface, and the descending waters, in the presence of oxygen and carbon dioxide and other reagents, have formed soluble sulphates from the sulphides, and redeposited them in part as oxides and carbonates of copper and lead above water-level, and in part as yellow and grey copper sulphides at and near water-level. There is no indication of a double period of ore concentration by secondary processes.

Relative Ages of Cobar Lodes and other New South Wales Lodes.

The Cobar lodes have been placed at the close of the Devonian Period for the present.

The New England deposits—copper, gold, tin, silver, bismuth, molybdenite, antimony, lead, and wolfram—north of Armidale, may be referred to the period which closed the Permo-Carboniferous sedimentation in that locality.*

The serpentine and its associated gold lodes in New England appear to have a late Carboniferous age. This subject will be described in the near future by Mr. W. N. Benson in a paper on the serpentines of New England.

In the Parkes–Forbes area, a series of lodes have been described by the present Writer, which occur in Ordovician rocks, and are absent altogether from the associated Silurian and Devonian sediments. These lodes appear at least to be pre-Devonian in age. The Broken Hill lode is of great age, and has been assigned by various observers to Silurian, or even to pre-Cambrian activities.

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* E. C. Andrews, Drake Gold and Copper Field, "Mineral Resources, No. 12," Dept. Mines, N.S. Wales, 1908.

PLATE XXIX.

H. Lowell Price. **Great Cobar Copper Mining Company.**

(Main Stack, brick-lined, self-contained. Height 200 feet ; inside diameter at top 14 feet.)

Chapter V.

DESCRIPTIONS OF MINES.

Mines o fthe Great Cobar Company.

Mines Considered.—The Great Cobar Copper, the Chesney, the Cobar Gold, and the Blue, Brown, and Conqueror Lodes of the Peak.

These mines may be fittingly described under the same heading, because they are owned by the one Company.

The Great Cobar Mine.

Situation.—The mine under consideration lies between the settlements of Cobar and East Cobar. The large smelting stack (Plate 29) is a landmark for 25 miles around, and serves to indicate the position of the township. Cobar Railway Station lies about half a mile to the north-west from the smelting stack, and is connected with the mine by a branch Government railway.

This mine is by far the most important in the district.

Leases—

	a.	r.	p.
Great Cobar Mine—			
Freehold	1,091	1	35
Special leases	1,551	1	0
Leases	119	0	19
	2,761	3	14

Portions 66 and 63, Parish Cobar, on which the Great Cobar Mine and smelters are situated, are freehold.

The following leases for fireclay, limestone, and magnesite are also held by the Great Cobar :—

M.L. 17, Parish Weltie, County Robinson, of 40 acres, for fireclay.

M.L. 57, Parish Cobar, about 8 acres, and Portion 49, freehold, Crown grant, Parish Buckwaroon, 40 acres ; both for fireclay.

M.L. 58, Parish Cobar, 25 acres, for magnesite.

M.L. 1, Parish Bee, 20 acres, for limestone.

History and Production.—The general history of the field has been supplied in another chapter, and only the main facts of the development of the Great Cobar are here supplied.

After the great flood of 1870, some tank-sinkers were camped at the "native well" which had been scooped out of one of the gossan outcrops now included in the Great Cobar Mine. Carbonate of copper was found by the tank-sinkers in the outcrop, and on the 6th October of the same year the outcrops were covered by a Mineral Conditional Purchase of 40 acres. In the middle of the year 1871 two other 40-acre blocks were secured, adjoining the original 40-acre block to the south and north. One of these was known as the Great Cobar North, and the other as the Great Cobar South. In January, 1876, the two southern mines were amalgamated under the present name of the Great Cobar. This Company consisted of 80,000 shares of £1 each.

Exceedingly rich oxidised ores were found in abundance, and these were forwarded to Port Adelaide Smelting Works, South Australia, by way of Louth, and, to a minor extent, by way of Bourke along the Darling River; 3,000 tons of ore, exceeding 25 per cent. copper, are reported to have been sent away at a profit. This ore consisted mainly of red oxides, carbonates, chalcocite ("grey" ore), and chalcopyrite (yellow ore).

Reverberatory furnaces were erected about this time, and in spite of the sub-arid climate and the distance (287 miles) from the railway line, the "Company was enabled to . . . pay dividends, amounting to more than two and a half times the total capital."*

In 1889 operations had to be suspended owing to the extremely low price of copper and excessive cost of transport."† An attempt was made in 1885 with blast furnaces (not water-jacketed), but discarded. In 1893 the Great Cobar Mining Syndicate secured a tribute of the mine, and successfully introduced water-jacketed furnaces.

Both this introduction of cheap blast furnaces and the opening of the railway line to Cobar in 1891 "revolutionised the copper industry at Cobar."‡

Between the period 1876–1903 about 213,182 tons of ore were raised, for a yield of 23,610¾ tons of copper. Droughts exercised a baneful influence on the mining industry before the days of the railway. "During a drought in 1882–3 it was found almost impossible to maintain the necessary supply of firewood, whilst the stock of copper in the sheds at the mine increased to over 1,200 tons owing to the impossibility of transport by team over 300 miles of drought-stricken country to the nearest railway.

"The water supply at this period became so restricted that armed patrols guarded the only available tank, and doled out a scanty allowance to the residents. Travellers were allowed but one drink for themselves and horses.

"Significant of the changed conditions is the fact of continuous operations during subsequent disastrous and protracted droughts."§

The Cobar-Chesney Mine was purchased in 1904, and its ore was smelted with that of the Cobar. In 1905 option of purchase was given to an English company, who secured the mine and its dependencies in 1906 for £800,000 cash. In that year a refinery and an electrolytic plant were established at Lithgow. Collieries also were secured.

In 1910 the Cobar Gold Mine was secured by the Great Cobar. During this year large ore bins were commenced, to hold a quantity of ore exceeding 12,000 tons, as against a previous provision for only 3,500 tons. The amount of ore treated during a working day averages about 1,000 tons.

The large mullock tank was connected this year with passes Nos. 2, 3, and 6, at a depth of 70 feet from the surface.

The main shaft was 1,260 feet deep in 1911. Two more levels are to be opened up, one at 1,350 and one at 1,450 (?) feet depth.‖

The average values reported by the directors in 1910 for the mine were 2·57 per cent. copper, ·025 oz. gold, and ·197 oz. silver. The metal contents of ground worked in No. 10 level are reported to be variable.¶

In 1911, the reported assay values of the ore reserves of this mine were: 2·60 per cent. copper, ·059 oz. of gold, and ·375 oz. silver. The ore reserves of the mine are stated to be 2,142,000 tons (exclusive of Cobar Gold, Cobar Chesney, and Peak Mines).

The total production of copper, up to the end of 1911, for the Great Cobar Mine is about 91,385 tons.

This includes Chesney returns since 1904 and Cobar Gold since July, 1910.

* J. E. Carne, "Copper-mining Industry," 1908, p. 230. † *Ibid.*, p. 230. ‡ *Ibid.*, p. 230.
§ J. E. Carne, *ibid.*, p 230. ‖ Shaft 1,400 feet deep in 1912. ¶ Directors' Report, 1909.

Development.—The underground workings of the Great Cobar Mine comprise twelve levels (Plate 30), whose general trend is about north 17° west and south 17° east. The main shaft is vertical, and has three compartments. The measurements of the shaft are about 15 feet 6 inches by 8 feet in the clear, and the depth is 1,410 feet. Barton's shaft is 1,000 feet deep, and below a depth of about 328 feet this shaft has been increased in width. The "New" shaft, situated to the west of the main shaft, is 900 feet deep, and is connected by cross-cuts with the main shaft.

No. 1 Level is irregular and about 100 feet in depth. No. 2 is 154 feet below the surface, and has a length of 1,200 feet. The depths below the surface of Nos. 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 Levels are 232, 328, 420, 525, 639, 745, 847, 997, 1,147, and 1,250 feet, respectively. The lengths of these levels are approximately 1,200, 1,100, 1,100, 1,075, 1,000, 1,050, 1,075 900, 950, and 151 feet respectively. The workings at No. 12 Level (1,250 feet) consist of drives, cross-cuts, and chambers, whose extreme measurements are 135 feet in width. No. 13 Level is being started.

The ore-bodies now being worked occur on the western portion of a mass of crushed country, and they consist of three lenses arranged along one line and separated by non-profitable networks of quartz veins and altered slate containing traces of copper. The maximum widths of the levels are approximately as follows:—No. 4 Level (Middle Lens), 110 feet; No. 5 Level (Middle Lens), 90 feet; No. 6 Level (Northern Lens), 85 feet; No. 7 Level (Middle Lens), 80 feet; No. 8 Level (South Lens), 120 feet; No. 9 Level (Middle Lens), 105 feet; No. 10 Level (Northern Lens), 160 feet*; No. 11 Level and No. 12 Level (Middle Lens), 130 feet (including 40 feet of poor central ore). (See Fig. 13.) The maps illustrate both the plans of the various levels and the longitudinal section, or "orthogonal projection," of the western workings. Cross-cuts have been driven to the east to prospect the eastern veins but no development work of importance has been done there.

The total length of ground explored is about 1,200 feet, the large ore-bodies known at present being limited to that length.

The ground stands well, except in certain places along its western wall where the lode has slipped on itself. Here a zone of rotten slate occurs, which necessitates care in opening up large stopes along this side of the ore channel. Wide open stopes are generally carried up to heights of about 25 feet. Beyond that height it is not considered advisable to carry them by the officers of the Department of Mines. A new scheme of mullocking is now being partially carried out by the management because of the difficulty of securing a payable output of the ore under the present system. Four passes in offsetting sections are shown on the maps. From the large mullock tank immediately west of the lode the slate waste is fed into Nos. 2, 3, and 6 passes direct by means of a tunnel and tramway 70 feet below the surface, but to feed the mullock down Nos. 1, 4, 5, and 7 passes, horses are employed to drag loaded carts up a steep incline. This method of mullocking, however, will doubtless soon be abandoned in favour of a scheme of mullock distribution down vertical offsetting passes connected to one or two main tunnels leading from the mullock tank.† The situation of the smelting plant and the workshops on the hill containing the outcrop prevents the adoption of an otherwise simple and effective method of mullocking, namely, by the formation of a great open cut where the smelting plant now stands, and passing the mullock below through vertical passes. Incidentally also, such

* The eastern portion of this lens has been worked in poorer concentrating ore, and it is doubtful whether the total 160 feet could be taken in estimating the width of the lens.

† See Inspector Polkinghorne's Report, Annual Report Dept. Mines, 1911.

method of mullocking would permit the winning of the rich sulphide and oxidised ores lying above the fourth level and estimated by the Company at about 97,000 tons. Of course, such an undertaking would necessitate the sinking of a main shaft in a fresh place. If the shaft were sunk to the east of such open cut, the cross-cuts to the lode would partially prospect the unknown eastern country.

The Country Rock.—The rocks exposed in the Great Cobar workings are of simple types, and consist of slates, which are yellowish and reddish to pinkish-grey near the surface, and which assume dark bluish-grey tints below water-level.

Certain differences exist between the slates composing this country; thus the slates east of the main lode are generally harder than those to the west, and they frequently split in such a fashion that the planes of cleavage are modified by numerous subconchoidal partings. On the other hand, the planes of cleavage in the western slates are almost perfectly developed. The western types also are more solid and "blocky" than those to the east, the latter being much broken up by subhorizontal joints. Among the eastern slates, however, a specially solid belt runs along the Old Bourke Road from the east of the mine to the Cobar-Nyngan railway line. This slate is of coarser type than the associated sediments, and, moreover, it is traversed by networks of tiny veins and strings of quartz which have silicified the slate in part. Distinct traces of siliceous gossan are to be seen at various points in and near this slate belt. The average of several measurements of strike for the eastern belt is about north 17° west, and the prevailing dip is high and in a westerly direction.

The strike of the "blocky" slates of red and greenish-grey colour, which are well exposed in the large mullock tank, to the west of the lode, is about north 30° west, and the dip appears to be towards the west and varying in value from 60° to 70°.

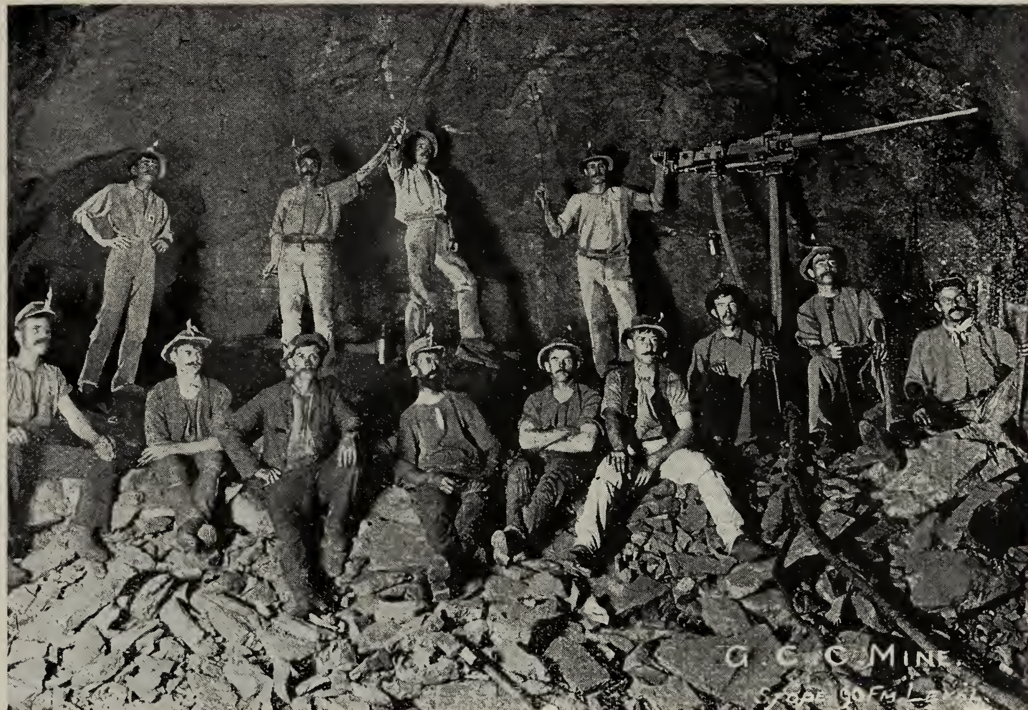
An examination of the yellow, chocolate, purple, white, and grey slates, which are exposed in the railway cuttings a little to the north and to the east, shows a general westerly dip, and a strike of about north-west. The accompanying analyses of the slates have been made at the Departmental Laboratory.

892–11.—Clayslate from the Open Cut, Great Cobar Mine.

Moisture at 100° C.	1·02	
Water above 100° C.	3·09	
Silica	62·13	
Alumina	19·06	
Ferric oxide	5·00	
Ferrous oxide	1·53	
Manganous oxide	0·02	
Lime	0·74	
Magnesia	1·70	
*Sodium chloride	0·31	
Soda	0·15	
Potash	4·43	
Titanium dioxide	0·72	
Phosphoric anhydride	0·15	
Sulphur trioxide	absent	
Chromium sesquioxide	do	
Strontia	present	Spectroscopic reaction only.
Lithia	do	
Vanadium sesquioxide	absent	
	100·05	

* Soluble in water.

(Analysis by Mr. W. A. Greig.)



Great Cobar Copper Mine.
(90-fathom level. Massive sulphide ore in face.)

1396-11.—Clayslate received from the east side of the Great Cobar Lode, Cobar.
Chemical Composition.

Water at 100° C.	0·74	
Water above 100° C.	3·12	
Silica (SiO_2)	63·06	
Alumina	19·42	
Ferric oxide	5·30	
Ferrous oxide	0·36	
Manganous oxide	trace	
Lime	0·24	
Magnesia	0·84	
Soda	0·44	
Potash	4·74	
Titanium dioxide	0·80	
Phosphoric anhydride	0·09	
Sulphur trioxide	trace	under ·01 per cent.
Nickel and cobalt oxides	absent	
Barium oxide	0·08	
Strontium oxide	present	Spectroscopic reaction.
Lithium oxide	do	
Vanadium oxide	absent	
Carbon dioxide	0·05	
Organic matter	0·8	
	100·13	

Gold and silver, a few grains per ton. Copper, a minute trace.

(Analysis by Mr. W. G. Stone.)

The Veins.—Several fissures occur in the Great Cobar property. The western, or main, vein is of great width, while in the more silicified slates to the east two other fissures occur, possessing an almost vertical dip. The origin of these eastern veins is doubtful, but is probably due to minor sub-parallel movements induced by the heavy dislocation which appears to have caused the western vein. Sufficient developmental work along these veins has not been carried out, however, to enable this point to be settled definitely, the information yielded by any surface exposures being practically negligible. In places the eastern veins appear as networks, which combine at various points to form more solid masses of quartz. This habit of the eastern veins to occur as subparallel and interlacing cracks following definite and narrow zones is strongly suggestive of crushing.

The main, or western, vein presents several rather peculiar features. Both it and the associated eastern veins lie in a zone of great strain, nevertheless, powerful as the vein is as it passes through the Great Cobar property, it can not be definitely traced on the surface north and south of that property. The Gladstone and other smaller veins to the south may lie on the main zone of strain to which the Cobar fissure belongs, but this idea implies the rapid passage of intensity of the movement to the west as the zone of strain in which the Gladstone occurs lies a short distance to the east of the Great Cobar zone (see map). To the north of the railway line the zone of strain in which the Great Cobar veins occur is indicated by several fissures, one of which is strongly marked, while it possesses the usual steep inclination to the east.

The outcrop of the western lode can be traced only for about 1,200 or 1,500 feet. Near the northern boundary of the Company's ground it passes under the waste sheet, and appears to be represented by a great width of ironstained-quartz on the surface, a little distance to the west of the main, or No. 3, shaft of the Great Cobar North. One of the peculiarities of the outcrop is the occurrence of local bulges which form three defined lenses of gossan. These are connected by quartz stringers. For short distances the western vein dips steeply to the west; at other points it dips steeply to the east. The general inclination is slightly to the east, but the vein is almost vertical.

In many places the western wall of the vein is fairly well defined, and shows signs of decided side slipping later than the formation of the fissure proper. Much crushed country occurs on this western, or foot, wall.

From a consideration of these various points, namely, the existence of different slates on opposite sides of the fissure, the variation of slate dips on the east and west sides of the vein, the occurrence of large lenses of ore along a zone of strain, the occurrence of networks of quartz veinlets disposed linearly, and from the slipping of the lode upon itself, it is probable that the western, or main, fissure of the Great Cobar has been caused by a strong dislocation formed under considerable load.

The Lenses.—These are not wholly composed of vein material, but in places contain large blocks of silicified slate. The lenses may be roughly divided into western and eastern portions, the western portion being basic, and the eastern portion acid. The acid lode material on the east appears to be more strongly developed from the eighth to the twelfth levels than above the eighth level, and is there in the nature somewhat of bands (Plate 22). Strings and small veins of quartz as networks frequently separate these western and eastern portions, while similar strings of quartz veins traverse the slate along the western side of the ore lenses, and connect them along a line about north 15° west. Similar lines of quartz veinlets in places follow the eastern portions of the lenses.

The maximum length of the lode measured along the three lenses is 1,200 feet, and the minimum length as opened up is 950 feet along No. 11 level. Not all of these lengths are worked, as the lenses are separated by blanks, the ore dying away north and south into the country from three distinct centres (incidentally also it may be stated here that the ore commonly dies out *gradually* into the eastern slates). The largest blank known between the lenses, as revealed by the mining workings, exceeds 200 feet in length and 200 feet in height. This occurs between the middle and northern lenses from the third to the fifth levels. It is possible, however, that the western half of this large block of virgin ground will be worked in the future. The average distance between the middle and northern lenses is about 140 feet. A portion of this belt of ore, at present unpayable, may, however, be mined in the future, under more economical metallurgical conditions. The width of the blank between the southern and northern lenses was about 50 feet in the upper levels, but above the fourth level they were practically continuous. The average width below the fourth level was 50 feet to the eighth level, thence, downwards, the width of the blank increased, as shown on accompanying map.

For the northern lens the average length is about 375 feet, and its average maximum width about 90 feet. Its width on No. 10 level is pronounced.

Photo. Great Cobar, Ltd.

Feeding Floor, Great Cobar Smelters.

Side-tipping Trucks.

425 feet is about the average length of the middle lens, and 80 feet is about its average maximum width. The width is exceptionally large on Nos. 9 and 10 levels.

The south lens is much smaller than the northern and middle examples, its average length is about 150 feet, and its average maximum width is about 50 feet. On the eighth level the lens is exceptionally wide, namely, 110 feet, the length being about 150 feet.

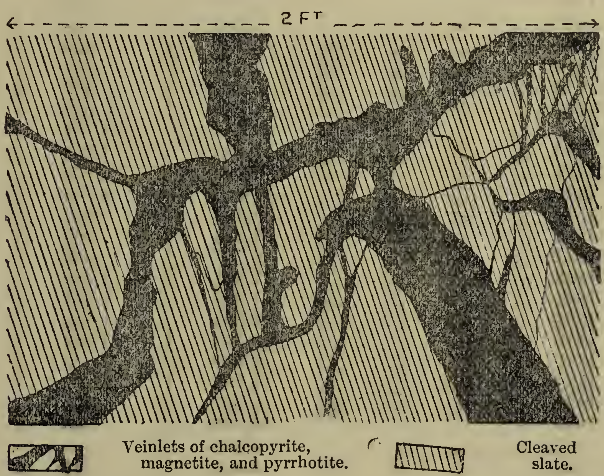


Fig. 12.

Detail of Ore Occurrence in northern face, northern Lens, No. 10 Level, Great Cobar Mine.

A slight tapering is thus indicated with increasing depth for this lens.

The pitches of the lenses in the vein are interesting. Thus, the middle lens shows a pitch of 350 feet to the north, between the fourth and eleventh levels. According to the mine plans the southern end of the northern lens as worked has a pitch to the north of 325 feet between the fourth and eleventh levels, that is, in a vertical distance of 820 feet. On the mining plans, however, the northern end of the northern lens is not shown as possessing a decided pitch to the north. The northern face on No. 8 level, however, is in ore. On No. 9 level the lode appears to have been disturbed, while on Nos. 10 and 11 levels the northern faces are wide and are still in good ore. Other particulars concerning the lenses may be found in the description of the ore itself.

Character and Occurrence of the Ore.—The usual carbonates, red oxide, black and yellow copper sulphides occurred in the upper portions of the mine, while the main mass of the ore below water-level consists of cupriferous pyrrhotite and magnetite associated with slate, chert, iron silicate, and quartz. Plate 22 and Fig. 12 illustrate the occurrence of Great Cobar ore

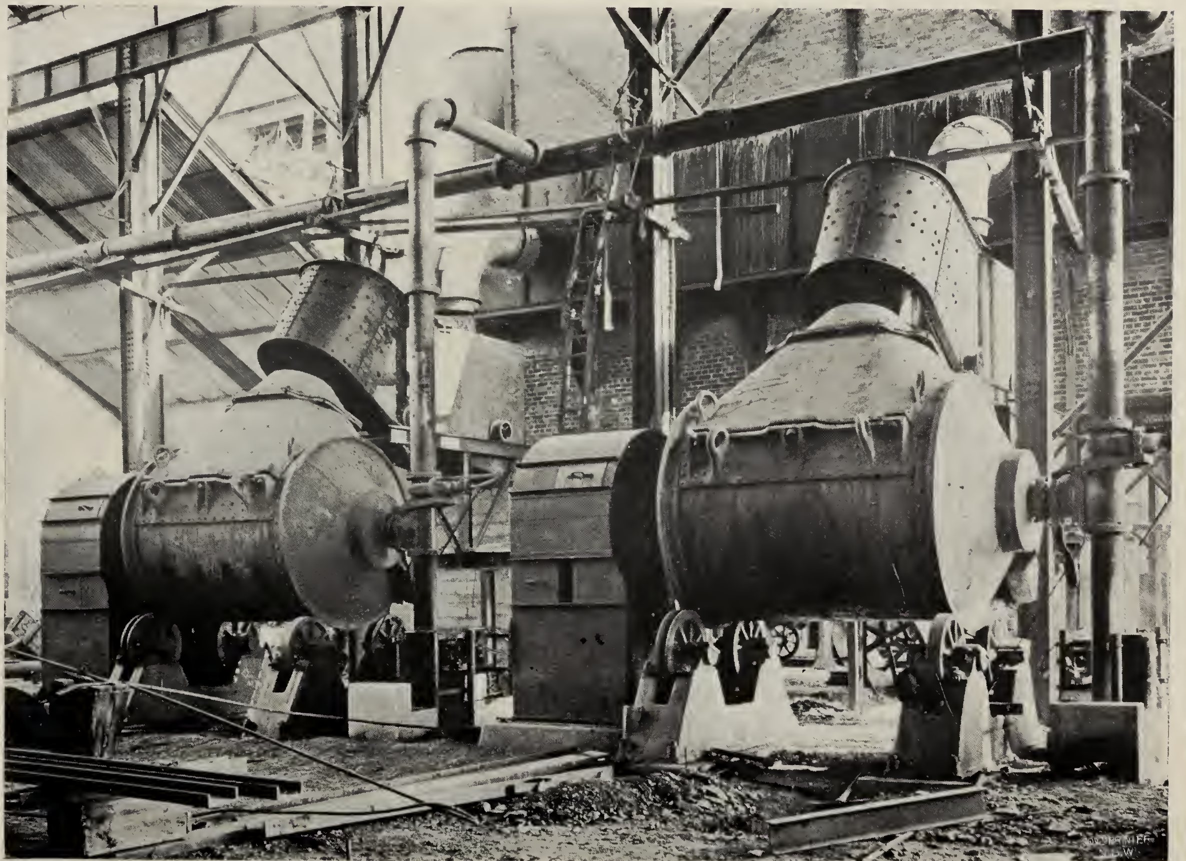
The following table, reproduced from page 243 of Mr. Carne's "Copper-mining Industry* for 1908," shows in a striking manner how the ore has changed with increased depth from the surface.

Output of the Cobar Copper Mine (Cobar–Chesney also from 1904, and Cobar Gold Mine from 1910).

	Ore.	Equal to copper.		
	Tons.	Tons.	Percentage.	
Period from 1871–1876	3,000	900	30·00	
Half-year ended :—				
31 December, 1876	1,458	174	11·93	Produced by the Great Cobar Copper Mining Company (31 December, 1876, to 3 August, 1889)
30 June, 1877	2,350	255	10·85	
31 December, 1877	2,530	268	10·59	
30 June, 1878	3,651	600	16·43	
31 December, 1878	4,738	857	18·08	
30 June, 1879	5,610	876	15·61	
31 December, 1879	7,005	1,015	14·48	
30 June, 1880	8,334	1,181	14·70	
31 December, 1880	11,890	1,388	11·67	
30 June, 1881	9,930	1,163	11·71	
31 December, 1881	11,622	1,405	†12·08	
30 June, 1882	5,882	942	16·00	
31 December, 1882	5,820	863	14·82	
30 June, 1883	6,772	955	14·10	
31 December, 1883	11,324	1,460	12·89	
30 June, 1884	11,876	1,361	11·46	
31 December, 1884	12,003	1,408	11·73	
30 June, 1885	11,558	1,064	9·20	
31 December, 1885	12,000	1,066	8·88	
30 June, 1886	14,000	1,093	7·80	
31 December, 1886	11,887	951	8·04	
30 June, 1887	10,840	888	8·01	
31 December, 1887‡	9,000	705	7·83	
30 June, 1888	5,500	416	7·56	
31 December, 1888	7,425	589	7·09	
3 August, 1889§	8,177	667¾	8·15	
1894‖	13,460	665	4·94	
1895	38,278	1,694	4·42	
1896	63,185	2,708	4·09	
1897	64,262	2,492	3·87	
1898	111,557	3,424	3·06	
1899	123,834	3,746	3·02	
1900	114,465	3,475	3·03	
1901	110,767	3,206	2·89	
1902	89,634	2,415	2·69	
1903	141,781	3,333	2·35	
1904¶	143,244	3,580	2·49	
1905	180,538	4,061	2·24	
To 21 August, 1906	108,032	3,108	2·87	
From 22 August, 1906, to 31 December, 1907	237,916	5,916	2·48	
1908	234,877	5,172	2·14	
1909	215,036††	5,072	2·36	
1910**	307,444‡‡	6,304	2·05	
911	352,149§§	6,548	1·86	
Totals	2,866,643	91,384¾‖‖	3·19	

* The returns for 1894, 1908, 1909, 1910, and 1911 have been added by the Writer to Mr. Carne's table, thus bringing it up to date.
† Inadvertently recorded as 1·208 in Mr. Carne's "Copper-mining Industry," 1908, p. 243.
‡ Inadvertently recorded as 1888 in Mr. Carne's "Copper-mining Industry," 1908, p. 243.
§ Eight months' output.
‖ Inadvertently left out of Mr. Carne's "Copper-mining Industry," 1908 p. 243.
¶ From 1904, Cobar–Chesney output also included.
** Since August, 1910, Cobar Gold-mines included.
†† From Directors' Report, October, 1910, p. 20, 42,718 tons; revert not counted.
‡‡ From Directors' Report, November, 1911, pp. 23, 24, 7,758 tons purchased ore included; but 73,919 tons revert not included.
§§ From Annual Report, 1911, p. 51.
‖‖ Total tonnage of Great Cobar copper to present (March, 1913), about 100,000 tons.

Great Cobar Copper Mine.
(90-fathom level. Lode, 70 ft. wide.)



H. Lowell Price.

Great Cobar Copper Mining Company.

(Nos. 1 and 2 Converter Vessels on blowing stands, with movable hoods, leading to dust chamber at back.)

Mr. Carne's notes of 1908* are also noteworthy when considered in connection with his table.

"The most important features of the latest mining development in the Cobar lode are improved width and sustained values in the lowest levels.

"At the north end, too, at 800 feet, in the lowest working level in that direction, values have improved beyond the upper poor zone,† where a basic mixture of pyrite with zinc and lead sulphides contain not more than 1 per cent. of copper.

"The inference deducible from developments at 1,000 feet, that values have become constant, is supported by the average annual grade of production since the oxidised ores were exhausted.

"The percentages since inception of partial pyritic smelting in 1895‡ afford instructive study, showing gradual depreciation from 4·42 in 1895‡ to 2·35 in 1903. For the ensuing four years the grade remained practically constant, namely, 2·49, 2·24, 2·87, and 2·48.

"Though these results are complicated by admixture each year of the product of several levels (as well as the Cobar-Chesney quota), still, as the higher are usually exhausted first, they may be regarded as fairly indicative of the rate of vertical depreciation.

"Though copper lodes, in common with other metalliferous bodies, show marked depreciation in value with augmenting depth, a limit to depreciation appears a natural corollary to enrichment consequent on superficial decomposition, leaching, and deposition at lower levels."

The table is very instructive, as illustrating the gradual passage from rich ores near the surface to ore of much leaner, but of fairly constant, value at depths considerably below water-level. No very large patches§ of rich ore appear to exist now above the fifth level, and the future of the mine depends upon the development of its lower ore-bodies. A consideration of the table shows that the mass of the ore extracted represents a recovery of less than 3 per cent. of copper. Thus, out of a total of about 2,860,000 tons won up to the end of 1911, about 2,010,000 tons have been raised since 1901 for a total of about 45,500 tons of copper, or an average of about 2·25 per cent. of copper. This represents the values obtained from the ore of the lower levels, and, as shown from the years 1901 till 1911, they are of fairly constant character.

It may be thought that the acquirement of the acid gold ores of the Chesney, the Peak, and the Cobar gold mines, and their treatment at the Great Cobar Mine, could be responsible for the fact that the copper values fall below 3 per cent. A careful examination of the table does not support this idea. In 1901, 1902, 1903, about 342,182 tons of ore were raised for a yield of 8,954 tons, or 2·6 per cent. of copper. In 1904 the Chesney was acquired, and its acid ores were fluxed with those of the Great Cobar Mine. Between the dates December, 1903, and December, 1909, 1,108,352 tons of this mixed ore yielded 26,647 tons of copper. That is 2·4 per cent. of copper.

In 1910 the acid gold ore of the Cobar Gold Mine was smelted with that of the Great Cobar and the Chesney, and the copper values for that year fell to 2·13 per cent., while in 1911 the copper values fell to 1·86 per cent. Nevertheless, in 1908 they yielded only 2·14, and in 1905 only 2·24 per cent.

* "Copper-mining Industry," p. 239. † From Mr. Carne's description, it is very probable that the younger and barren lead-zinc vein had formed here at the expense of the chalcopyrite and pyrrhotite of the earlier vein. ‡ Inadvertently this date has been printed 1905 in "The Copper-mining Industry." § About 97,000 tons of rich ore are reported to exist above the fourth level.

In this connection it will be at once evident from chemical considerations that only a certain percentage of these acid ores can be used in conjunction with the basic ore of the main lode so as to obtain the best smelting conditions. Thus, in 1910, 241,764 tons of Cobar ore, 33,391 tons of Chesney, and 24,221 tons of Cobar Gold were smelted together. Assuming that Cobar and Chesney ore yielded 2·5 per cent. Cu, and Cobar Gold only 1·3 per cent. Cu, then the influence of the Cobar Gold ore in smelting would be to reduce the general copper production by ·10 per cent. only. The acid gold ores of the Peak have only amounted to about 22,000 tons, and such amount is negligible in comparison with the 2,000,000 tons of copper ore with which it has been smelted. Moreover, thousands of tons of rich copper ore have been bought by the Great Copper Mine from the Budgery, Tinto, Gladstone, and other mines. These copper enrichments have been included in the Great Cobar returns, and would counterbalance the non cupriferous character of the Peak ores which have been smelted with the Great Cobar ore.

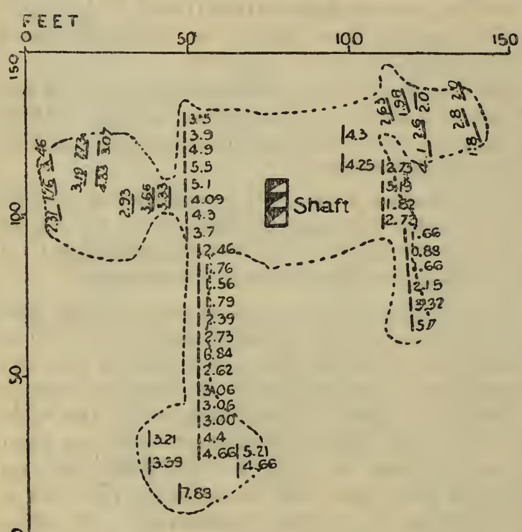


Fig. 13.

Copy of assay plan of No. 12 (1,250 feet) Level, as supplied by Great Cobar, Ltd. The numbers represent copper percentages in 5 feet lengths. The average value of copper for 115 feet taken across lode as recorded by 23 assays is 3·79.

Fig 2, Plate 22, is a sketch of the eastern portion of No. 12 Level.

A careful consideration of the actual returns published therefore points to the fact that the actual recovery of copper from the lower levels of the Great Cobar Mine is more like 2·00 than 2·50 per cent.

It may be stated that the assay value of the primary ore of the mine itself is put at 2·60 per cent. copper, with a working value of 2·5 per cent. copper [and a loss of about ·25 per cent. in the slag].

Attention should, however, be drawn to the fact that the yield for 1911 appears to have fallen below 2 per cent. of copper. Thus, 352,149 tons of ore were smelted that year for a return of 6,548 tons of copper, or 1·86 per cent. copper. This certainly cannot be attributed to a depreciation of the copper content in the ore at the lowest levels, as an examination of the stopes will show. In fact, some of the finest assays of primary ore have been made along No. 12 level. In the published assay plan of the chamber and cross-cut at the twelfth level (1,250 feet), the average copper value appears to be about 3·8 per cent.

It must be remembered that the northern lens has not yielded copper values equal to those of the middle lens, and in past years there has been a decided tendency to win a greater percentage of ore from the middle than from the northern lens. During the past year or two an attempt has been made to work the mine upon a different plan.

Photo. Great Cobar, Ltd.

Great Cobar Furnaces.

"In 1908, 33 per cent. of the ore was drawn from the North Shoot, 54 per cent. from the Middle, and 13 per cent. from the Southern Lens. It was readily seen that a continuation of this policy would, within a short space of time, leave the mine in a very unsatisfactory, if not serious, condition. It was, therefore, decided that the ore should be drawn proportionately to the reserves in the various stopes. This resulted, in 1909, in varying the quantities from the above as follows :—40 per cent., 45 per cent., and 15 per cent. respectively. During the past year 55 per cent. of the total ore was drawn from the Northern stopes, only 31·88 from the Central, and 13·12 per cent. from the Southern."*

By this means the mine is getting more into shape, but in the meantime the copper percentage in the returns has decreased.

In contradistinction to this apparent uniformity of copper values in the primary ore it may be well to consider the character of the lode in the upper levels. Two extracts from Mr. Carne's report† are here reproduced so as to bring out the strong contrast between the values of the oxidised bodies and the lower sulphides.

> " *Development.*—The position of the mine, six years after the formation of the Company, is best presented by reproduction of the following extract from a report furnished to the Under Secretary for Mines by the General Manager, Mr. George Hardie‡ :—
>
> . . . .
>
> " *Becker's Shaft.*—Good ores exist from the surface to the bottom. At the 26-fathom level the lode in the shaft is 24 feet wide, composed of carbonate and grey ores. At this level drives have been put in north 130 feet, and south 270 feet, proving the lode to be on an average 18 feet wide, and worth 14 per cent. At 39-fathom level drives have been put in north 90 feet and south 110 feet, the lode averaging 12 feet throughout of good ores. At the 54-fathom level the lode is proved to be at least 17 feet wide of sulphurets, worth 22 per cent.
>
> " Barton's shaft is 600 feet south of Becker's. At the 15-fathom level drives have been put in 191 feet, the lode averaging 15 feet of good carbonates. At the 26-fathom level drives have been put in north 180 feet, and south 161 feet—the lode throughout these drives will average 40 feet wide of grey, carbonate, and oxide ores of good quality. At the 39-fathom level drives are in north 136 feet, and south 80 feet, the lode throughout being fully 15 feet wide, with 14 per cent. At the 54-fathom level the same sulphurets precisely have been cut as in Becker's shaft at the same level.
>
> . . . .
>
> "Renwick's shaft, 260 feet south of Hardie's, is connected with Hardie's at the 15 and 26-fathom levels, proving the existence of first-class ores. No work has been done south of Renwick's shaft.
>
> . . . .
>
> " This mine has been at work three and a half years, during which period 18,993 tons of ore have been smelted, yielding 2,683 tons of refined copper (14·1 per cent. copper), (which assays 99·5 to 99·60 per cent.) valued at £160,980."

* Directors' Report, Nov., 1911, pp. 13 and 14. † " Copper-mining Industry," 1908, pp. 232–233.
‡ Ann. Report Dept. Mines for 1878, p. 24.

The following extract, also from Mr. Carne's "Copper-mining Industry," page 245, illustrates the richness of the ore from the upper levels of the Southern Cobar Copper Mine before it was acquired by the Great Cobar Company:—

"During the half-year (1874) 220 tons of good ore raised, and 150 tons despatched from the mine. The quality of the ore can be judged from the following account sales from Adelaide:—

Tons.	Assay per cent. (Copper).	Tons.	Assay per cent. (Copper).
15	40·750	15	37·125
58	35·750	4	26·250
22	26·625	14	42·250
14	27·375	3	43·000
8	43·125	23¼	44·
5	44·625	30½	42·
12	38·250	6½	43·500
4	26·375	18	42·75
13	36·750	12⅓	39·50

The following quotation from the same report (p. 231) also throws light on the quality of ore extracted from the upper levels. The quotation is from a report by the late L. H. G. Young*:—

"The ore from the 50-fathom level is composed of solid yellow sulphide of copper; from the 39-fathom level, of carbonates, metallic copper in films, red oxide, grey sulphide, and brown iron ore, the lode being fairly compact.

"At the 26-fathom level the ore is principally carbonate of copper, mixed with iron ore, while the lode is less compact."

We see, then, that in the Great Cobar lode a lean gossan was found at the surface. At a depth of from 50 to 230 feet, rich and large masses of carbonates were found. Red oxide, grey and yellow sulphides formed very large and rich patches (17 to 30 per cent. copper) near water-level. At moderate depths again, below the water-level, the rich grey sulphide disappeared, and the chalcopyrite became less pronounced in quantity. Below the sixth level, however, the ore was ascertained to possess fairly constant characters.

This is important, as it suggests that the present 2·5 per cent. ore constitutes the mass of primary deposition which has not been altered by surface or descending waters. The future of the mine thus appears to depend upon the continuation in depth and size of the lenses, and other considerations. The discussion of these points, however, is deferred to a later stage.

"*Composition of the Ores.*†—The composition of the rich ores from the upper levels may be well studied in the following analyses, made by Mr. W. A. Dixon.‡ It will be observed that bismuth was present in marked quantity, but apparently the major portion of it was eliminated during smelting operations, as revealed by the analysis of the copper produced from the ores analysed (No. 65). It is noticeable that in a recent analysis of drillings from the 50, 74, and 90-fathom levels (sulphide zone), its presence was not detected. Possibly it may be confined to certain regions of the lode, and in the oxidised zone leaching and redeposition may have concentrated it in appreciable quantities.

* Ann. Rept, 1880, p. 262.
† J. E. Carne, "Copper-mining Industry," 1908, pp. 234–235.
‡ Ann. Rept., 1878, pp. 25–29.

ANALYSES of Cobar Copper Ores, by W. A. Dixon.*

Assay Numbers.	56	57	58	59	60	61	62	63	64	65
Silica	4·26	2·06	·62	1·92	·96	20·68	·56	10·64	29·28	....
Copper	22·84	54·06	37·87	54·93	26·47	63·24	57·42	42·79	38·23	99·346
Antimony.. ..	·61	traces.	traces.	traces.	·46	·13	traces.	....	....	0·29
Bismuth	2·11	1·47	1·90	2·58	2·17	1·18	·95	1·24	·21	·419
Lead	·27	·41	·45	....	....	....	7·79	....	....	·086
Arsenic	traces.	....	....	....	....	....	....	....	....	·011†
Iron	39·20	7·28	30·80	18·26	39·09	1·74	4·99	8·49	·78	·083
Zinc	·35	....	....	....	....	....	....	....	....	....
Silver	traces.	traces.	....	....	....	....	....	....	....	·026‡
Nickel	....	traces.	traces.	....	....	....	....	....	....	....
Magnesium ..	....	5·33	....	....	....	....	traces.	....	....	....
Sulphur	24·11	4·18	18·63	14·48	27·46	5·70	11·67	....	....	....
Carbonic Acid ..	....	9·97	....	....	....	traces.	5·87	14·37	17·47	....
Water	....	3·41	....	....	....	....	4·60	7·04	3·79	....
Water, oxygen (less water), loss undetermined, &c	6·25	11·83	10·00	7·83	3·39	7·33	6·15	15·43	10·24	....
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

† Traces of arsenic, nickel, cobalt, gold, loss, &c. ‡ Equal 8 oz. per ton.

Sample 56. Copper pyrites and magnetite.
Sample 57. Red oxide, copper glance, and ferric oxide.
Sample 58. Copper pyrites, red oxide, and ferric oxide.
Sample 59. Copper glance, with ferric oxide.
Sample 60. Copper pyrites and magnetite.
Sample 61. Copper glance and red oxide.
Sample 62. Copper glance, with malachite.
Sample 63. Malachite, with ferric oxide.
Sample 65. Copper from the above.

"The nature of the sulphide ores at Cobar is partially revealed by the following analysis made in the Departmental Laboratory from drillings obtained by the Writer through the courtesy of Mr. T. Longworth, of the Cobar Syndicate. The sample was intended to represent an average of two days' drillings at the 50, 74, and 70-fathom levels; the copper contents, however, may be disregarded, as they do not represent the average value of the ore in these levels, which, according to the smelting returns, ranges between 3·2 and 4·4 per cent. :—

Moisture at 100° C.	0·20
Metallic iron	42·65
Do copper	10·15
Do lead	trace
Do zinc	,,
Silica	16·09
Alumina	0·44
Lime	absent
Magnesia	0·34
Sulphur	20·74
Sulphur trioxide (SO_3)...	0·23
Oxygen (by difference)...	9·16
	100·00

Silver, at the rate of 1 oz. 21 dwt. 21 grs. per ton.

Gold, a trace (under 2 dwt.)

NOTE.—A large amount of magnetite is present in this sample."

* Ann. Rept., 1878, pp. 25–29.

ANALYSIS of Great Cobar E.L.C. Copper by Messrs. Dixon and Byrn, Analysts, 97, Pitt-street, Sydney.*

Gold	0·0001 per cent.
Silver	0·0013 ,,
Antimony	Nil.
Arsenic	0·00100 ,,
Lead	0·0009 ,,
Selenium	Trace.
Telurium	Nil.
Bismuth	0·0018 ,,
Zinc	0·0018 ,,
Nickel...	0·0031 ,,
Oxygen	0·037 ,, =(Suboxide of copper, 0·3317)
Copper	99·95462 per cent. (By difference)
	100·00000 per eent.

In connection with Mr. Carne's suggestion as to the bulk of the bismuth being probably confined to the upper levels, the following note to the Writer by Mr. A. W. Hudson, Manager of Cobar Electrolytic Works at Lithgow, may be of interest:—"I presume Weed's statement refers to the Cobar ore in the early days. I believe that some of the ore did carry a quantity of bismuth. . . . . If they had bismuth, arsenic, and antimony it would cause some trouble in the early days in casting the copper, as they probably could not make it tough enough. This would be due to the method used. . . . . Bismuth does not occur in quantities as it used to in Cobar, and therefore no trouble is experienced. These metals cause most of the trouble during electrolytic treatment by fouling the solution. . . . We do not experience any trouble now on account of these metals."

The accompanying assays of Great Cobar primary ore have been made recently in the Departmental Laboratory. The first is from a stope in the north end of the northern lens above No. 9 level, while the second is from the younger and practically worthless lead vein on the same level.

—Massive Pyrrhotite with Chalcopyrite on No. 9 Level, north end of north lens, Great Cobar Mine.

Copper	17·00 per cent.
Silica	5·00 ,,
Iron	42·00 ,,

No. 576.—Great Cobar Mine, No. 9 Level, western wall, north end of north lens. Mixed sulphides in crushed clayslate.

Gold	A trace.
Silver	4 oz. 2 dwt. 18 grs. per ton.
Copper	None detected.
Lead	18·00 per cent.
Zinc	19·78 ,,
Iron	14·00 ,,
Sulphur	23·11 ,,
Silica	8·02 ,,

Plate 22, Fig. 1, illustrates the general occurrence of the ore in one section taken across a stope in the northern lens at a height of about 25 feet above No. 9 level.

Oxidized Ores.—Azurite occurred as large masses of radiating fibres, with secondary malachite developed between the fibres. A feature of the mine was the great development of beautiful fibrous, mossy, and concentric growths of malachite. In the Departmental Museum a fine specimen of

* J. E. Carne, "Copper-mining Industry," p. 244.

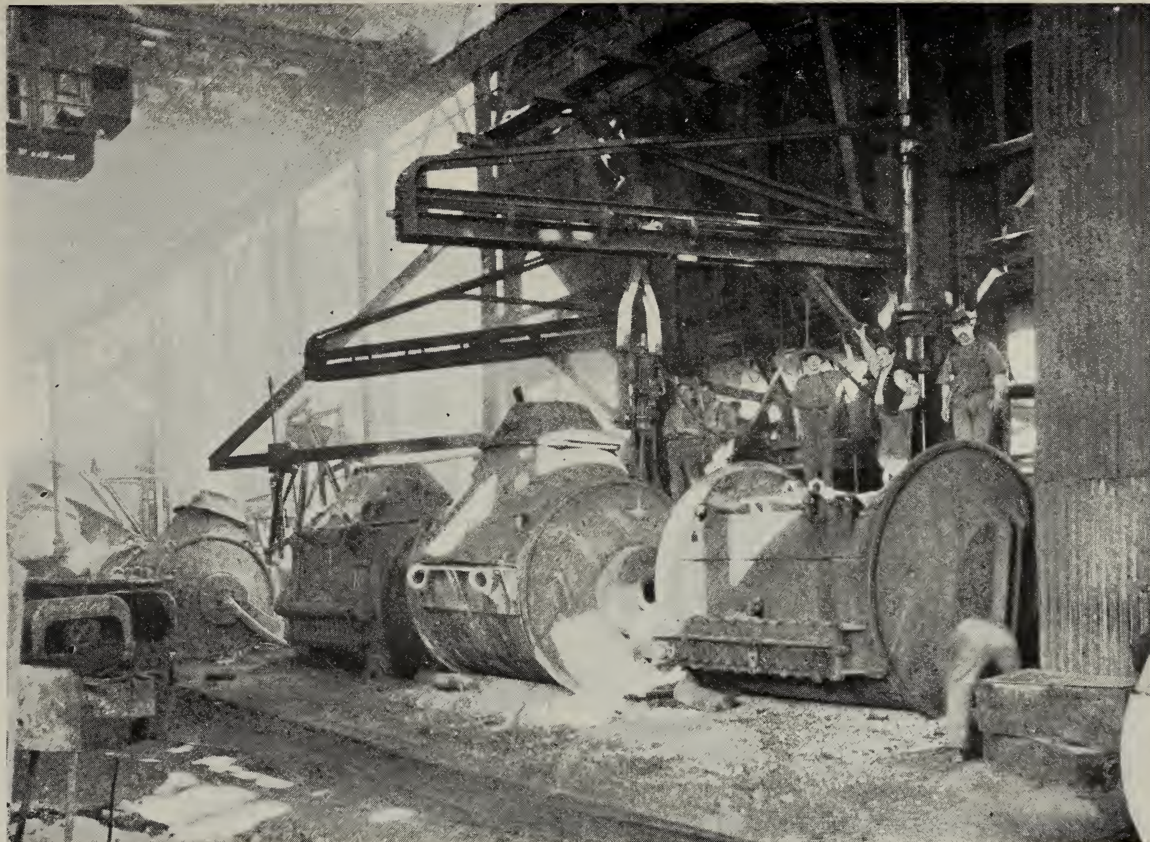


Photo. Great Cobar, Ltd.

Relining Converters, Great Cobar Mine.

ranching or coal-like growth of cuprite occurs, encrusted with both fibrous nd amorphous malachite, with crystals of azurite sitting upon the malachite. he cuprite is of the resinous red variety, the malachite slightly mossy on the urface. The azurite has been deposited by wandering surface solutions. he rich secondary sulphurets which occurred above the cupriferous pyrrho-ite consisted of chalcocite (grey ore) and chalcopyrite (yellow ore).

Gold in Great Cobar Copper Ore.—Gold was known to be present in the reat Cobar Copper Mine in the early days of the field, inasmuch as coarse nd scaly samples had been seen near the surface both in the ferruginous late and in the carbonate ore. As early as 1881 an assay had been made in he Departmental Laboratory from a sample of ingot copper, and this had ielded :—

Gold	2 oz. 12 dwt. 4 grs. per ton.
Silver	1 oz. 5 dwt. per ton.
Copper	92·65 per cent.

Nevertheless, although this result was made known, the Great Cobar ompany did not attempt to benefit by it until the latter half of 1894. The immediate result* was an advance of about £7 per ton over the current uotations for Chili bars."

" The sulphides from the working stopes in 1898 were reported to yield from ¼ to 3 dwt. of gold per ton. . . . . . The market value of the Cobar opper is now enhanced some £20 odd per ton by the contained gold and ilver." Mr. Carne points out that this great enrichment is not altogether ue to the concentration of the ores of the Great Cobar Mine itself, but artly also by the use of gold and silver ores from other mines.

The following analysis is of mine water secured from the pump delivery of he Great Cobar Mine :—

11–786.—Mine Water from the Great Cobar Mine.

	Grains per gallon.
Lime	30·828
Magnesia	32·278
Ferrous oxide	11·468
Alumina	6·412
Silica	3·976
Soda	73·026
Potash	1·728
Strontia	trace.
Cobaltous oxide...	0·392
Nickel oxide	2·464
Manganous oxide	0·859
Copper oxide	3·829
Chlorine	86·628
Sulphur trioxide...	145·765
Carbon dioxide	......
	399·653
Less oxygen equivalent to chlorine	19·577
	380·076

A minute trace of arsenic detected. Water acid.

(Analysis by Mr. J. C. H. Mingaye, F.C.S.)

Faulting of Ore Bodies.—No cross-faulting of importance has occurred in he Cobar Mines. A fault producing a displacement of 10 or 15 feet would carcely be noticed, inasmuch as the lodes, in extreme cases, exceed 120 feet n width. Mr. Inspector David Milne has mentioned the occurrence of a fault rom the south end of the south lens. Mr. A. J. Lindsay, of the Great obar Company, has also noted this system of cross-faulting.

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* Carne, "Copper-mining Industry," p. 237.

A slip upon the old strike-fault main plane, in which the pyrrhotite and magnetite had been deposited, has occurred. This has been discussed already. Lead, zinc, and iron pyrites appear to have been introduced by this movement, but these minerals have not been economically important. This faulting has produced that loose unstable appearance along the western side of the lode, whereas the effect of the sulphide and silica replacement during the first great shattering movement was to cement the country tightly together.

Future Development of the Great Cobar Mine.—The increasing difficulty experienced by the associated mines in treating the acid gold ores of their deeper levels illustrates the growing importance of a large central pyritic body such as that under consideration. Mr. J. E. Carne* in 1899 pointed out that the Cobar Gold Mines, the Occidental, the Mount Pleasant, the Young Australian, the Great Western, and the Peak Mines were securing the gold contents of the mines by free milling methods and by cyanidation. Even at that distant date he pointed out that these mines were "betraying signs of copper admixtures with increasing depth, presaging the stage reached in the Cobar-Chesney Mine, where free milling had given place to cupriferous lodestuff, unamenable to such treatment, and yet too lean for direct smelting as copper ore."

> "To a depth of about 150 to 200 feet free milling and cheap cyanide extraction processes are possible and profitable; below that level, for 100 feet or more, the lodestuff is stained with oxidised copper ores; then, after an intermediate stage of partial oxidation, the permanent copper sulphide zone is reached.
>
> "Mechanical concentration offers little prospect of successful achievement in the oxidised lodestuff."

He further pointed out that the "cogency of the opinion expressed in 1899 is quadrupled in 1905."

> "The possibility of smelting the cupriferous ores from the Fort Bourke (Cobar Gold Mine) and Chesney-Occidental lines of lode is, so far as indications go, discounted by the absence of sufficiently concentrated iron sulphides and the nature of the matrix. Judging by the Cobar-Chesney sulphides and the concentration products therefrom, the clean sulphides are comparatively rich in copper and low in iron. The matrix of these ores, consisting of slate, quartzite, and quartz, requires a large proportion of iron for fluxing. Failing command of cheap and abundant supply, the mines along these lodes cannot hope to establish independent smelting plants on a profitable basis.
>
> "The disabilities under which they labour throw into strong relief the possibilities and potentialities of the immense pyritic resources of the Great Cobar copper lode. This kindly fluxing base, in the Writer's view, is the key to the situation, and must, if persistently basic, in the near future exert controlling influence, unless a radical change is discovered in yet untested levels in the other mines. The urgency of deep testing, preferably by diamond drilling, is therefore apparent."†

Mr. Carne also pointed out how "The Cobar-Chesney Mine, after vain expenditure of capital and labour, fighting the difficulties of a separate existence after the free-milling ores were extracted, was absorbed in the operations of the Great Cobar Copper-mining Syndicate." He also pointed out (p. 203), "that each of the mines mentioned has already, or will shortly, encounter the same difficulties that confronted the Cobar-Chesney, namely—increasing

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* "Copper-mining Industry," 1908, pp. 201–204. † *Ibid.*, p. 202.

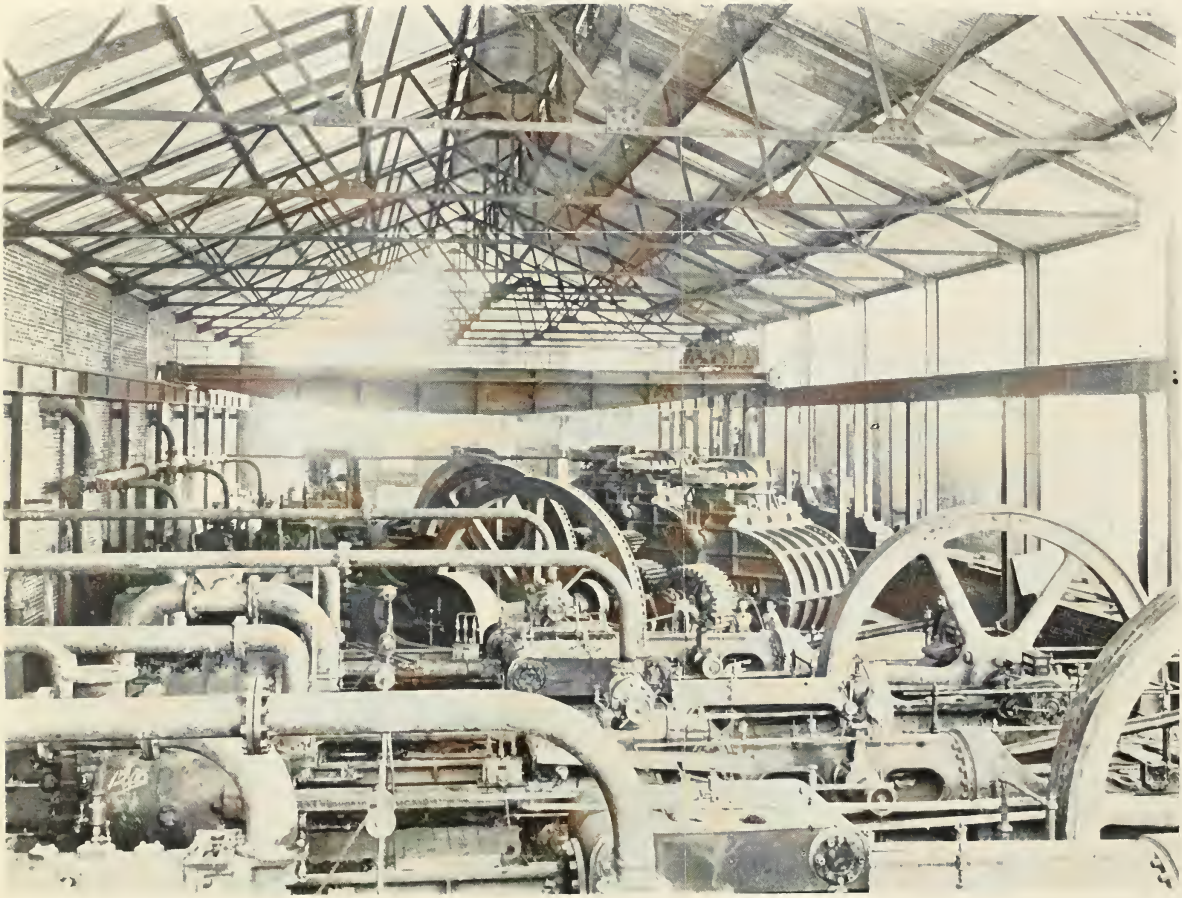


Photo. Great Cobar, Ltd.

Compressors and Blowers, Great Cobar Mine.

copper contents preventing cheap gold extraction, yet insufficient for direct smelting. The fundamental difference between the cupriferous ores of these mines, so far as proved, and that of the Great Cobar copper lode lies—as already stated—in the nature of the matrix. Even if their copper contents were doubled, they would still be unsmeltable, save at considerable cost for concentration and fluxing."

"Unless a vital change, as yet unindicated, occurs in the constitution of the lodestuff at lower levels yet unreached in the other mines under consideration [the fate of being absorbed by the Great Cobar Mine appears to await them] *providing* always that the pyritic resources of the Great Cobar copper lode persist undiminished in solidity and comparative freedom from silica."

There is little to add in this connection to Mr. Carne's clear account of the lines along which the field would probably be developed. It is interesting, however, to note that mining developments have proved the soundness of his deductions. Thus the important Fort Bourke (Cobar Gold) Mine has been acquired by the Great Cobar, and its acid gold sulphide ores are being smelted with the basic sulphides of the Great Cobar; the important Occidental Mine has had to modify its plan of campaign owing to the exhaustion of the free-milling ore and the presence of only acid sulphide ores at the lower levels.

It is evident, however, that in running even for a bisilicate slag the Great Cobar can only smelt a limited amount of the associated acid, gold, and copper ores. For whereas the Great Cobar possesses about 41 per cent. of iron it nevertheless possesses from 16 to 22 per cent. of insoluble matter, mostly as silica, and unless some special precautions were taken, such ore would only be of sufficient basicity to flux itself. But by making use of the *converter* slag the requisite amount of iron for smelting a fair percentage of outside acid ore is forthcoming. Attached are two weekly averages of assays of converter slags:—

	Percentages.	
Copper	·96	1·60
FeO	59·40	59·90
SiO_2	31·30	29·90
Al_2O_3	7·70	6·20

The averages of dump slag for a considerable period are as follows:—

	Percentage.
FeO	50·00
Insol.	40·00
Al_2O_3	6·50
CaO	·20
Cu	·25

Future Life of the Pyritic Bodies.—In the first place, the tonnage of ore won from the Great Cobar (inclusive of Cobar-Chesney ore since 1904) is nearly three millions.

Mr. J. D. Kendall, Consulting Engineer, estimated that the *ore in sight* on the 31st December, 1907, was 1,400,000 tons for the Great Cobar Mine and 499,999 tons for the Chesney Mine. The report on this estimation contained a modifying note, namely:—

"Although in the above figures the ore in the middle shoot has only been calculated to 75 feet below the 850-feet level, it should be stated the ore body has actually been proved at the 1,000-feet level to fully maintain its width and values."*

* Carne, "Copper-mining Industry," p. 241.

In the Directors' Report of 1st October, 1910 (p. 6), the ore *reserves* on the 31st August, 1910, were computed as 2,877,000 tons for the Cobar and Chesney Mines, as against 2,383,000 tons in December, 1909. Their report also contained the following note on these estimates:—"The above figures do not include the low-grade ore, estimated at about 650,000 tons, in the working levels of the Cobar Mine, which our manager believes can be treated at a good profit, by adopting methods now in use in the United States."

Towards the close of 1911 the ore reserves of the mine were estimated by the Company's officials to be 2,142,000 tons. [Directors' Report, November, 1911, p. 16.]

Before the introduction of the picking belt, practically everything which was mined went through the smelters, and thus, in making a check upon the estimates of the Company, it was considered sufficient to ascertain the areas of the sill levels by planimeter, and to multiply the areas so found by the heights of the unstoped portions respectively lying between the various levels. This approximate method of computation gave a tonnage of 2,000,000 tons between the Nos. 4 and 11 levels, if the specific gravity of the ore be considered as about 3·75.

Permanence of Lode and Lenses.—At the outcrops the lenses rarely exceed 30 feet in width. At the fourth and fifth levels the widths are much greater, while at the eighth, ninth, and tenth levels the lenses are as much as 120 feet wide in places. The development work on No. 11 level has also proved the great width of the lenses at this depth, while the cross-cut at 1,250 feet depth is about 130 feet in length (middle lens), and averages about 3·78 per cent. of copper according to the assay plan of the Company.

An examination of the working levels indicates that a shortening of the lenses is taking place with depth, although the areas of these levels themselves do not appear to have diminished; in other words, that which is lacking in length in the lenses appears to be made up in width.

The southern lens is almost vertical, and is suggestive of a carrot form. The middle lens as worked shows a decided pitch to the northward—a pitch of 305 feet northward horizontally in a vertical distance of 820 feet. The northern lens, as worked, shows a decided pitch to the north of its southern extremity; nevertheless the northern extremity is shown on the orthogonal projection as having an almost negligible pitch northwards. This may be due to either—

(1) An actual diminution of the lens in length and a tendency to adopt the carrot form; or

(2) A decision on the part of the Company to discontinue working northward on the first sign of either pinching of the lens or of decrease in copper values.

When one considers the probability that these lenses are arranged *en echelon*, vertically as well as in plan, it certainly seems a pity that no low-level drive has been run to the northern boundary of the Company's property, so as to prove the huge block of virgin ground to the north. The North Cobar Company, at 1,450 feet depth, struck the general mineral association of the Great Cobar along the same line in 1911, and this is additional reason why such low-level drift should be run.

The whole appearance of the three ore masses is strongly suggestive of true lenses which are lenticular not only in plan but also in transverse section. Such an interpretation implies that not much of the lenses has been carried away by the action of denudation.

It also implies a disappearance at some finite depth of the lenses as exposed in the present mining workings. On the other hand, so slight is the alteration in area of the levels in the middle and northern lenses, from the fifth to the tenth levels inclusive, that everything points to the continuation of these lenses to much greater depths than at present exposed. The workings on the south lens suggest that this mass separated from the middle lens near the fourth level, and that it has perceptibly decreased at the seventh and tenth levels. The south lens, however, is small as compared with the middle and northern ore-bodies on the same line. It, however, suggests the gradual tapering of both the middle and northern lenses at some depths unascertained as yet.

Despite this apparent lenticular form of these ore-bodies, it must be distinctly understood that the areas of the levels on both the middle and northern lenses appear to be about as great on the ninth and tenth levels as in the higher portions of the lode.

By planimeter measurements of the levels, as shown on the Company's working plans at the close of 1910, the areas of the lenses along No. 8 level were as follows:—Northern Lens, 19,125; Middle Lens, 16,875; and Southern Lens, 7,700 square feet.

Along No. 9 level, planimeter readings:—Northern Lens, 13,500; Middle Lens, 24,075; and Southern Lens, 2,250 square feet.

Along No. 10 level:—Northern Lens, 19,000 (not completely opened up); Middle Lens, 19,800; and Southern Lens, not properly opened up. The average of the Southern Lens may be struck from Nos. 8 and 9 levels.

These figures show some fluctuations in area, considered from level to level, and, moreover, the areas supplied here are, doubtless, too great, because they have been taken from the small working plans of the Company, in which everything stoped or excavated is indicated as ore.

If, now, the average of such ascertained sill floor areas be found and multiplied by 150 for the distance in feet between two levels in sequence, and if the ore be assumed to have a specific gravity of 3·75, then the expected tonnage from the Northern Lens, between two adjoining levels, is about 280,000 tons; from the Middle Lens, about 325,000 tons; and from the Southern Lens, about 75,000 tons. If, however, this estimated quantity from the south lens be considered too great, then the expected tonnage between levels 150 feet apart may be put down at about 670,000 tons.

Another method may also be adopted for ascertaining the probable tonnage between individual levels 150 feet apart at depths greater than any yet exploited. It consists of adding the tonnage of ore mined already to that of the ore reserves, and estimating the tonnage contained in an average mass of ore 150 feet in depth.

Thus the total tonnage mined is approximately 2,850,000 tons, and the total ore reserves down to the 1,150-feet level may be put down at 2,100,000 tons. This would give a total of 4,950,000 tons of ore as far down as the eleventh level. The tonnage of the ore above the 100-feet level may be neglected in this calculation for various reasons already set out in this report.

Thus within a depth of 1,050 feet a total tonnage of about 4,900,000 tons has been found, and one-seventh of this, or 700,000 tons, is the average expected tonnage between two levels 150 feet apart. In this calculation it will be seen that no allowance has been made for ore developed between the twelfth and eleventh levels, and in such case the expected tonnage may be reduced to between 650,000 and 700,000 tons.

From these estimates, and from the notes already supplied, it is almost certain that the mine has a considerable life before it, but it is not the less remarkable that no attempts have been made by the Company to form some sort of estimate of the ore-bodies below the twelfth level, either by means of sinking or by means of the diamond drill. This is all the more remarkable because the Great Cobar Company is singularly fortunate in possessing a series of ore lenses which offer such few difficulties in the matter of exploitation. Thus there are three lenses of ore almost vertical, and arranged along a definite line. There has been little cross-faulting to complicate operations and zones of negligible value arranged horizontally to dishearten the Company. Moreover, the average tenor of the ore in the lower levels has been fairly constant. It is possible that the basic ore may not be consistently wide along the lower levels. Thus on the eleventh level, the basic ore forming the west side of the lode in the middle lens did not appear to exceed 25 or 30 feet in width in any one place, while its average width appeared to be less than this amount. The width of the acid or banded ore, on the other hand, appeared to be increasing along the lower levels. The ore itself is basic even on this eastern side, but it is scattered as strings through a mass of valueless slate. (Plate 22.)

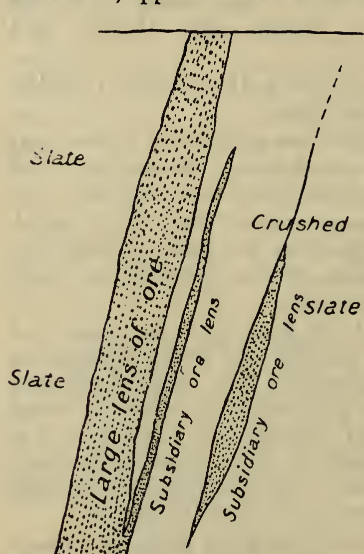


Fig. 14.
Sketch section illustrating necessity for use of diamond drill in crushed country where ore lenses may occur without definite outcrops.

The sinking of shafts or drills to a further depth of 500 feet would, if the interpretation of the lenses here supplied be correct, probably demonstrate the existence of about 2,000,000 more tons of ore, a quantity about equal to the total ore reserves known to exist at present. Not only so, but in such shattered country where *lenses* of ore have been developed apparently *en echelon*, it is remarkable that the diamond drill has not, until recently, been much used to explore the shattered ground in a lateral direction, in order to pick up any other lenses which may be arranged vertically *en echelon* with the main ore-bodies.*

Fig. 14 illustrates how Ore Lenses may occur *en echelon* in shattered country like that of Great Cobar.

In this connection it is perhaps not too much to advance the opinion that the wealth of the Great Cobar lenses would never have been suspected had the surface of the plain upon which the Great Cobar lodes outcrop been formed at a level of 1,000 feet higher than it is at present.

The peculiarity of some other huge lenses of copper ore formed along shear or fault planes may be here mentioned in this connection.

In an admirable summary of the Huelva Mines in 1910,† A. Moncrieff Finlayson points out how the huge ore-bodies of that district form lenses at the contacts of slate and porphyry, the contacts themselves consisting of great fault or shear planes.

* Work with the diamond drill was introduced during 1910 and 1911 in the Nos. 4, 6, 9, 10, and 11 Levels of Great Cobar, and it was thus found that the ore-bodies could be worked to a much greater width than had been formerly believed.

† The Pyritic Deposits of Huelva, Spain. Economic Geology, Vol. V, 1910, pp. 421-425. Figs. 40-42.

Photo. Great Cobar, Ltd.

New Slag Dump, Great Cobar Mine.

Outcropping lenses cut out rapidly with depth, while others were ascertained by underground workings to be related to subparallel lenses which never reached the surface. A famous example is the association of the lenticular ore-bodies known as the 5 per cent. and the 3 per cent. lodes. (Fig. 42, p. 425.) The 5 per cent. lens outcropped, whereas the associated 3 per cent. lens made no outcrop, but commenced on a feather-edge at a considerable distance from the surface.

The well-known Mount Lyell Coppér Mine forms a huge lens along a shear zone between schists and altered arenaceous sediments,* and the main geological and economic features have been ably described by Gregory. It outcropped as a large ironstone (hæmatite) mass, which passed into solid pyritic ore at a moderate depth. The lens tapers rapidly with depth, and at a depth of about 750 feet the diamond drill fails to record the existence of any but insignificant pyritic bodies. Gregory† explains this absence of ore at depth by faulting, but the phenomenon may be explained equally simply by considering it as a lens which has tapered rapidly. It is certainly lenticular in plan, and the areas of the lower levels decrease rapidly with increase of depth.

Mount Morgan is a huge lens of pyritic ore which occurs apparently at a contact of various rocks. On one side the ore ends almost abruptly, while on the opposite side it dies out gradually into the country. The plans of the levels are blunt ellipses.‡

These four famous examples of lenticular pyritic deposits appear to have been formed in shattered rocks along zones of strong dislocation, or at points of structural weakness, *e.g.*, Mount Morgan. The peculiar lenticular forms, and the mineralogical composition, suggest replacements either at points of cross or slip faulting, or at points where the rock has suffered intense local shattering.

It is evident that the Cobar lenses are not of the blunt type, such as some of those described by Finlayson for the Huelva deposits, and by Gregory for Mount Lyell; but they rather suggest the forms which the Huelva types might assume by indefinitely increasing their vertical measurements. In this connection, also, the miner of the Cobar ore should keep in mind the occurrence of those Huelva types, in which the sheared country carries lenses which do not outcrop, but which come in on a feather edge hundreds of feet below the surface.

The Cobar-Chesney Gold and Copper Mine.

Leases.—The mine under consideration is held by the Great Cobar, Limited. The numbers of the mineral portions are 12, 19, 23, 44, 58, 61, 68, 106, and 107, having a total area of about 98 acres. A freehold of 100 acres is also included.

History and Development.—The area now worked as the Chesney was the southernmost of a series of twelve 40-acre mineral lease blocks (at 10s. per acre), taken up in 1872 by Messrs. Ogilvie, Becker, Cornish, and others, and surveyed by Mr. Dalglish. At that time the rise upon which the Chesney is now worked was known as Mount Tabor, after a hill named in Scripture. The name was changed about the year 1887 to The Chesney, when the locality was first exploited carefully for gold.

* Gregory, J. W., Mount Lyell Mining Field, Australian Institute Mining Engineers, Melbourne, 1905.
† *Ibid.*, pp. 91, 92. ‡ See also J. M. Newman and G. F. Campbell Brown, "Geology of Mount Morgan," Procs. Aus. Inst. Mining Engineers, May, 1910, pp. 267-282.

"Two tons from the outcrop, treated at the Sydney Mint, yielded a little over 4½ oz. per ton. In the following year 28 tons were forwarded to Victoria. Fourteen tons under ordinary battery treatment yielded 1 oz. 17 dwt. per ton. The other 14 tons, under chlorination, yielded 2 oz. 3 dwt. 15 grs. per ton. A further test of 31½ tons yielded about 2¼ oz. per ton.

"In 1888 four leases, totalling 25 acres, 'were recently purchased by a Melbourne syndicate and floated in Melbourne into 100,000 shares, in the name of the Chesney-Cobar Gold-mining Company (No Liability). This Company also purchased 100 acres of freehold land adjoining . . . ."*

"In 1889, 2,436 tons yielded 796 oz. 12 dwt. from a lode 4 to 25 feet in width,† equivalent to about 6½ dwt. per ton."‡

"A large quantity of the auriferous impregnated slate from the oxidised zone was treated by battery and amalgamation, for an average yield approximating to 7 dwt. of gold per ton. The outcrop betrayed no evidence of the copper ores below; at 150 feet carbonate stainings became very marked. Sulphides began to show about 250 feet from the surface, the chalcopyrite being coated with melaconite (black oxide)."§

Another extract may be here quoted from Mr. Carne's book (p. 198), illustrating the development of the mine about thirteen years ago:—"During a visit in 1898, when the main shaft was down 460 feet, a cross-cut at 360 feet, through the lode, revealed a thickness of 40 feet. A level had been driven 550 feet along the lode, from which two other cross-cuts intersected the lode, showing its width to be persistent throughout the distance proved. The assay values, obtained by chipping across the face of each cross-cut through the lode, were as follows:—

"Cross-cut 200 feet, south of main shaft; average yield, 5 per cent. copper.

"Cross-cut (main) from shaft; average yield, 3 per cent. copper.

"Cross-cut 350 feet, north of shaft; average yield, 8 per cent. copper.

"The gold contents approximated from 2½ dwt. to 3 dwt. per ton."

As the copper sulphides came in it became difficult to extract the gold by the ordinary methods. In 1901 about 4,500 tons of the ore were smelted at the Great Cobar, the average yield being 3 per cent. copper and about 1 dwt. of gold per ton.||

In 1904 the mine was sold to the Great Cobar Syndicate, and has since been worked in conjunction with the Great Cobar Mine.

In 1907 Mr. Carne (p. 199) again visited the mine, and ascertained that the greatest depth of proving was 700 feet; its greatest length, 820 feet; its greatest width, 92 feet; the average width being from 35 to 40 feet. It had narrowed towards the south end.

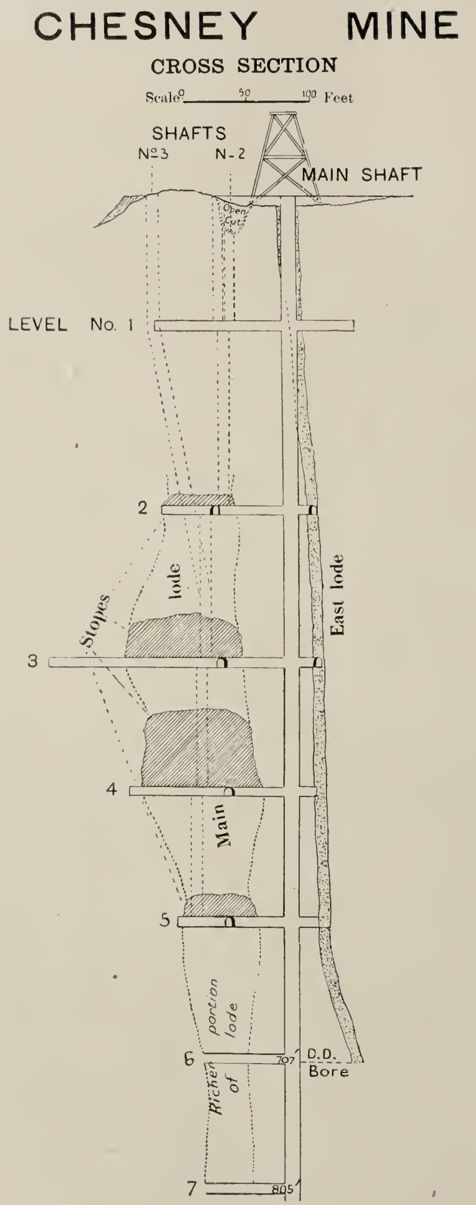
The average copper contents revealed during this later development were about 5 per cent.; gold was present to the extent of 15 to 24 grs., and silver to the extent of from 1 to 2 oz. per ton (smelting returns).

The accompanying notes on the development of the Chesney in 1908, 1909, and 1910 have been supplied by the management of the Great Cobar, Limited.

In 1908 the average monthly output was 4,020 tons, as against 3,461 tons per month in the previous sixteen months. Stoping was fairly uniform between Nos. 1, 2, 3, and 5 levels.

* Ann. Rept., 1888, p. 123. † Ann. Rept., 1889, p. 18. ‡ J. E. Carne, "Copper-mining Industry," 1908, pp. 208-209. § *Ibid.*, p. 198. || Ann. Rept., 1901, p. 53.

Plate XXXVIIa.



From the surface to No. 5 Level, section reproduced from Mr. Carne's "Copper Mining Industry," 1908, opposite p. 199. Information for section of Nos. 6 and 7 Levels taken from Company's Plans. Only the richer portion of the lode is represented for these lower levels.

"No. 6 level was put out from the shaft at a depth of 692 feet, and the ore ross-cut for 60 feet. The grade in that cross-cut is low, averaging about ·15 per cent. copper, ·007 oz. gold, and ·018 oz. silver,* but the width is uch greater than in level above. The quantity of ore blocked out at the 31st)ecember of similar quantity to that worked during the year, that is about ·25 per cent., was 576,500 tons, about 78,500 tons more than at the end of 907."†

During 1909, 208 feet of driving, 39 feet of rising, 79 feet of winze-sinking, nd 47 feet of cross-cutting were carried out, and an average of about 3,440 ons of ore were raised per month, and sent to the Great Cobar smelters. 'he directors state that suspension of labour conditions was granted to mullock and operate the mine economically."

Much low-grade ore broken in the mine was used to maintain the output.

"The urgent demand at the smelter for a satisfactory siliceous ore for use as onverter lining and for concentration purposes, resulted in exploration being ndertaken to the south on Nos. 4 and 5, where the workings exposed a vein om 4 to 6 feet wide of copper-bearing quartz. As work progressed to the outh the ore opened out to a width of 17 feet for a distance of 110 feet, hen the body again gradually narrowed to 6 feet."‡

The tonnage of ore blocked out to 31st December, 1909, was stated to be 96,670 tons.

Stoping during 1909 was a special feature between levels Nos. 2 and 3.

In 1911 the shaft was sunk another 100 feet, and a drive was put into the outh to pick up the downward continuation of a rich "pipe" of ore, which ad been worked just to the south of the main shaft, on the sixth level. 'he "pipe" was found to have increased in size from 417 square feet on he No. 6 level to about 2,000 square feet on the seventh level, while the high alues of copper and gold found on the sixth level continued to the eventh level.

A diamond drill bore from the No. 6 level is said to have proved the *eastern* ein to be about 40 feet east of the main shaft, and to contain about 3·5 er cent. copper. Its width is said to be about 8 feet.

The main shaft is 805 feet deep, No. 3 shaft is 353 feet, and No. 4 shaft is 25 feet deep. All these shafts are vertical. The mine is worked by seven evels. These occur at depths from the surface respectively of 100, 240, 362, 64, 562, 692, and 800 feet, and their lengths at the end of September, 1911, ere about 450, 780, 720, 1,200, 788, 375, and 100 feet respectively. The aximum width of the ore occurs at the north end of the lode, and appears o be of the nature of a "pipe," or lens, which has a maximum width of 85 feet n No. 3 level and of 75 feet on No. 4 level. Upon the third, fourth, and fth levels the ore-body is remarkably uniform in width for lengths varying rom 300 to 450 feet in length. The sixth level also gives promise of aintaining the average width of the higher levels. This average width is bout 34 feet. If to this massive body the large lens be added, into which he ore-body makes to the north, the average width would probably exceed 0 feet.

The maps illustrate the plans and longitudinal section of the mine. The ttached plate is a transverse section of the Chesney reproduced from Ir. J. E. Carne's "Copper," facing p. 199, and brought up to date September, 1911).

* These values improved later. † 1908, Directors' Report, p. 14.
‡ 1909, Directors' Report, pp. 14 and 15.

Production.

Cobar-Chesney Gold and Copper Mine.

Year.	Ore Raised.	Treated.	Yield.			
			Gold.			Copper
	tons.	tons.	oz.	dwt.	grs.	tons.
1887	....	2	9	0	0	......
1888	....	59½	127	6	0	......
1889	....	2,436	796	12	0	......
1890	....	880	586	0	0	......
1891	....	......	885	8	11	......
1892	....	......	....			......
1893	....	328	222	9	0	......
1894	....	1,985	1,019	0	0	......
1895	....	1,781	288	0	0	......
1896	....	2,440	436	0	0	......
1897	....	......	....			......
1898	....	......	....			......
1899	....	......	....			......
1900	....	......	....			......
1901	....	4,500	225	0	0	135
1902	....	420	9	10	0	......
1903	....	1,140	53	10	0	27½
1904	16,885·11	16,885	Included in Great Cobar returns.			Included under Great Cobar returns.
1905	45,310·73	45,310				
1906	26,613·73	26,613				
1907	....	......				
1908	51,579	51,473				
1909	41,272	40,679				
1910	34,236	32,076				
1911	22,431	22,919				

These returns can only be considered as approximate, inasmuch as they are incomplete.

Occurrence and Character of the Ore.—The general width and appearance of the main vein is indicated in the section. It occurs, as has already been mentioned on pages 71 and 86, along a zone of dislocation. Like its more important associate, the Great Cobar, several veins occur in its zone of crushing and shear. Of these, the one which has been formed in the soft slates near their junction with argillaceous sandstones, is the more important example. This is the western lode, which is of the nature of a compound lens formed along the line of a strong quartz vein running about N. 17° west and S. 17° east.

A large mass of impure jasperoid quartz occurs at the surface along the northern portion of the fissure, and its appearance is strongly suggestive of an alteration of slate by siliceous and iron solutions at a depth. This western vein lies about 40 feet west of the shaft on the surface and at the first and second levels. A strong eastern vein followed the main shaft down to the first level, while cross-cuts from Nos. 2, 3, 4, 5 and 6 revealed the presence of this eastern vein.*

In September, 1911, the diamond drill is said to have proved the vein to be about 8 feet wide on the No. 6 level, and to lie about 40 feet east of the main shaft. Mr. Carne (p. 199) in describing this fissure wrote : " About 75 feet east of the main lode, a 4-feet vein was worked to No. 1 level for gold. It has since been opened by cross-cut from a lower level, where its gold value is estimated at 6 dwt. per ton, with fair copper value also."

* See Plate facing page 190 of Mr. Carne's " Copper-mining Industry," 1908.

During the years 1910 and 1911 another rich "pipe" or shoot of ore has been worked just south of the main shaft on Nos. 6 and 7 levels. On No. 7 level (800 feet down) this pipe had increased in area as compared with that on the sixth level. Its average value, as worked by a stope 20 feet in height, was reported to be about 3·98 per cent. copper and about 9 dwt. of gold per ton. The shoot as worked on this level was 24 feet wide and about 76 feet long, and at the face was about 15 feet wide. This shoot on the sixth level was reported to have yielded average values of 6·5 per cent. copper and 10 dwt. of gold.

Both eastern and western veins dip easterly at very high angles.

The minerals found in the Great Cobar Mine occur also in the Chesney; nevertheless, the general appearance of the veins presents several striking differences. In the Cobar Mine the pyrrhotitic content is very pronounced, whereas in the Chesney it is almost negligible. Magnetite appears to occur in small quantities in the latter ore-body, but in large masses in the former one. In the Great Cobar Mine silica is quite a subordinate feature, especially in the free state, whereas in the Chesney it is a marked feature both as ordinary quartz and as the more flinty forms. The roofs of the large stopes in the Chesney often present a remarkable appearance by reason of the peculiar rectilinear patterns assumed by the numberless quartz veins and veinlets. One set of quartz veins, or elongated quartz lenses, parallels the general direction of the main lode, while another set is disposed at right angles to the major set of elongated lenses. Many of these veinlets are exceedingly delicate in appearance, and the general effect produced along one level is that of some beautiful geometrical pattern (Fig. 15). The spaces between the quartz veins and veinlets are occupied by slate changed to flint, chert, or siliceous slate, by reason of the wholesale introduction of silica along this wide zone of crushing. Veinlets of chalcopyrite, galena, and zinc are also associated with these quartz veins. The whole appearance of the ore-body suggests the formation of the lode by slow shearing and parallel slipping, or by a movement of the cleavage planes of the sandstone and slate over each other, and by the entry, at a slightly later date, of mobile solutions which replaced the slate and sandstone country in part to silica, and sulphides of iron, copper, galena, and zinc.

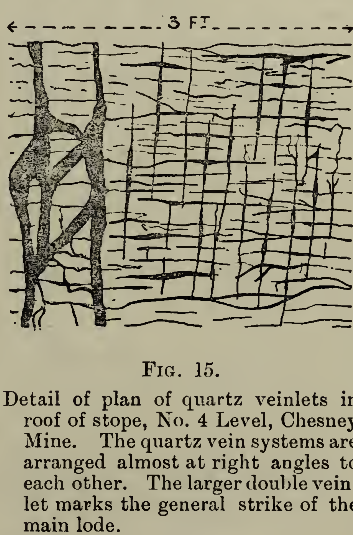


Fig. 15.

Detail of plan of quartz veinlets in roof of stope, No. 4 Level, Chesney Mine. The quartz vein systems are arranged almost at right angles to each other. The larger double veinlet marks the general strike of the main lode.

The outcrop of the Chesney was free from copper. At 150 feet it began to show freely in carbonate form, and as sulphides at about 250 feet. The carbonate ore between the 150 and 250 feet levels was estimated by Mr. Carne to average about 6 per cent. copper and the sulphides to contain about 20 per cent. iron.*

* "Copper-mining Industry," pp. 199 and 209.

The Chesney is computed by the Great Cobar Company (Limited) to have ore reserves to the amount of 600,000 tons of an average value of 2·8 per cent. copper, ·048 oz. of gold, ·378 oz. of silver, 12·5 per cent. iron, and 56 per cent. silica.

The sulphides are associated with slate and quartz, the slate fragments at times giving the idea of a breccia cemented with quartz and sulphides.

"The presence of copper gradually prevented profitable gold extraction by ordinary milling practices. . . . .

"So far as the lode has been pierced—over 700 feet—it has given no sign of concentrated ore-bodies, the copper and iron sulphides being disseminated through the slate and quartz matrix."*

Mr. Carne also reported (p. 199) that a short gold shoot had been followed down from the surface, the occurrence being of "pipe"-like appearance. Three ounces of gold to the ton were procured from this shoot.

The copper ore from the primary sulphide zone is chalcopyrite, which succeeded the richer chalcocite and chalcopyrite masses at and near water-level. This primary chalcopyrite is of high grade when clean. It is disseminated through the quartz, quartzite, and the slate country in threads, bunches, and veins sometimes several inches in width.

The accompanying quotation from Mr. Carne's "Copper-mining Industry, 1908" (p. 198), illustrates the values found in the higher levels of the Chesney :—

> "Further indication of the value of the ores in the Cobar-Chesney lode is afforded by the following assay determination quoted by Mr. T. Longworth, in the prospectus of the Cobar-Chesney Company, 1897, p. 16 :—
>
> "NOTE.—All the assays are fire assays, and should be fully worked up to.

Sample.	Copper—Fire Assay.	Corrected to Chemical Assay.	Gold per ton.
	per cent.	per cent.	dwt. grs.
No. 1. Carbonate from No. 3 shaft, 155 feet deep	2½	3·8	3 6
No. 2. Carbonate from No. 3 shaft, 214 feet deep	3	4·3	3 6
No. 3. Sulphides from No. 3 shaft, 275 feet deep	2½	3·8	3 6
No. 4. Sulphides, No. 1 shaft, 360 feet deep, south drive	4½	5·8	a trace.
No. 5. Sulphides from No. 1 shaft, 360 feet cross-cut	3	4·3	3 6
No. 6. Sulphides as mined from the whole of the lode in Nos. 1 and 3 shafts	3	4·3	3 6

> "The assay value of the ore as shown in these samples is about 1 per cent. lower in copper, and almost identical in gold with the ore at present mined and treated at the Great Cobar Copper-mine.—THOMAS LONGWORTH, Manager, Great Cobar Copper-mine, Cobar, 29th October, 1897."†

Water-level and Chesney Mine Water Analyses.—Water-level was found at a depth of 360 feet, and the amount made was about 50,000 gallons a day. Another water-level was met at a depth of 700 feet while sinking the shaft.

* "Copper-mining Industry," 1908, p. 198. † *Ibid.*, p. 209.

Pho'o. T F. Lean.

View of Chesney, Occidental, and Peak Mines from South End of Fort Bourke Hill.

Photo. Great Cobar, Ltd.

Chesney Mine.

Mr. Carne, in October, 1908,* reported that this lower flow was "equal to 300,000 gallons per day, now making about 250,000, and standing 85 feet below No. 5 level, present pumps incapable of reducing it lower." At present the water makes at the rate of about 100,000 gallons a day.

The following analysis of the Chesney Mine water was carried out at the Departmental Laboratory by Mr. W. A. Greig :—

No. 788-11.

Analyst, W. A. Greig, 7 April, 1911.

Analysis.	Grains per gallon.
Lime (CaO)	16·590
Magnesia (MgO)	27·440
Ferrous iron (FeO)	1·000
Alumina (Al_2O_3)	·868
Silica (SiO_2)	6·496
Soda (Na_2O)	137·566
Potash (K_2O)	trace.
Strontia (SrO)	trace.†
Copper oxide (CuO)	0·210
Chlorine (Cl)	164·811
Sulphur trioxide (SO_3)	49·888
Carbon dioxide (CO_2)	13·600
	418·469
Less oxygen equivalent to Cl.	37·131
	381·338

† Spectroscopic reaction only.

Water alkaline.
The absence of cobalt, nickel, and manganese proved.

The following analysis of the Chesney Mine water was made at the laboratory attached to the Great Cobar Mine :—

	Grains per gallon.
$CaCO_3$	18·9
$MgCO_3$	·42
$FeCO_3$	1·01
Fe_2O_3	·56
Na_2SO_4	146·93
NaCl	284·69
Na_2CO_3	2·70
$MgCl_2$	26·85
$CaCl_2$	14·06

Future of the Chesney.—The simplicity of the occurrence of the Chesney lode, namely, the persistence of the slate and sandstone walls, the one on the west and the other on the east, the absence of any but insignificant cross-faultings and other movements of the lodes, allow a certain definiteness of statement to be made with regard to possible future developments. In all probability similar geological conditions to those existing in the ground already worked will be found obtaining at much greater depths. The compound lens at present worked does not depend for its enrichment on cross-fractures, nor upon any extremely localised rocks, such as patches of crushed limestone in contact with diorites or porphyries, but depends rather upon a simple association of weak crushed slate and denser sandstone ; and this association is almost certain to continue to considerable depths, inasmuch as it continues for miles along the surface, and its dips are invariably high. Of course, the lenses themselves depend upon some peculiar structures in the slates, such as crumpling against the sandstone masses, or as side slipping and local shearing, whereby replacement of the relatively weak slates has

* "Copper-mining Industry," p. 199.

been possible ; nevertheless, the shapes of the lenses indicate that the ore-bodies must persist for considerable depths. The ore now worked at 700 and 800 feet depth appears to be almost entirely primary in character.

The Cobar Gold Mine.

Leases.—This property consists of gold leases 23, 38, 48, 50, 51, 52, 84, 131, and 171. A special lease of 50 acres, situated near the Show Ground, is also used for water-storage purposes. The leases and freehold of this and the adjoining Chesney total 477 acres.

History and Development.—The hill upon which both this important mine and its neighbour, the Chesney, occur, was known as the Fort Bourke Hill about the year 1887, and for seventeen years after the discovery of the Great Cobar Mine this long and and low rocky ridge was covered with dense vegetation. Although only one mile away from the parent mine, it lay almost unheeded until 1887. In that year the Mining Warden for Cobar stated that the gold industry in his district had been "in a languishing condition for the last two or three years. . . . During the last six months a decided improvement had taken place, in consequence of gold being discovered within 3 miles of the town. . . . Thirty-nine applications for leases of 258 acres were received, and five applications for prospecting areas. There are about forty men working on the United and Fort Bourke Hills, the same line of reef running through both hills for a distance of about 3 miles. Some of the shafts are sunk from 20 to 50 feet, showing fine gold in most of them."*

It is singular that this important lode should have been overlooked until 1887, inasmuch as it forms a bold outcrop on the western edge of the highest residual in the neighbourhood of Cobar. Moreover, the length of the payable shoot worked from the surface exceeds 600 feet, and its width varies from 20 to 50 feet.

In 1889 the Fort Bourke Tunnel Company, with 64,000 shares, was formed to work this hill. A tunnel was driven about 500 feet into the hill without success. As late as the year 1890 the tunnel driving had been unsuccessful in proving a large ore-body. Trial crushings, however, had yielded results of about 3½ dwt. of gold to the ton.

In 1891, 600 tons of stone were crushed for an average yield of 5 dwt. of gold to the ton. During the remainder of the period 1890–1900, work on this lode appears to have been of fluctuating nature. In 1894, 1,474 tons of stone were treated for 509 oz. of gold, but from that date onwards until 1900 there are no returns available in the records of the Department of Mines. In that year both this and the adjoining properties were secured by Messrs. Janin and party, who proposed to erect a large cyanide plant on the slope of the Fort Bourke Hill.

By the year 1900 the Cobar Gold Mines, Limited (better known as Fort Bourke), had sunk their main shaft to a depth of 236 feet, and had excavated a large tank (120,000 cubic yards), known as O'Gorman's Lake, but in 1902 the mine was closed down from the 1st March to the 30th November. After a further chequered career the mine was acquired by The Great Cobar, Limited, in August, 1910.

As with all the other mines along this line, the Cobar Gold Mine was payable while mining operations were confined to winning the free-milling stone above water-level. That level appears to have been about 325 feet

* Ann. Rept., 1887, p. 107.

Photo. T. F. Lean.

Fort Bourke Hill looking South-east.

deep. At a greater depth, however, the same difficulty which had been met in the associated mines along the same line faced the Fort Bourke Mining Company.

Various methods have been employed from time to time to overcome the metallurgical difficulties. Sliming, cyaniding, and the Elmore Vacuum Process were amongst the methods adopted. The accompanying quotation from Mr. Polkinghorne's report is interesting in this connection :—

" . . . About all the free-milling ore has now been extracted from the Cobar Gold Mine. At the No. 3, or 250-feet level, the lode has been driven on about 500 feet in length, and a cross-cut put in, which proves the lode to be upwards of 80 feet in width and of fair gold value, but the presence of copper makes the ore difficult to treat. Pending the erection of a different plant work will be confined to sinking and driving."*

Mr. J. E. Carne also reported :—" The exceedingly fine physical character of the gold in the leached zone doubtless accounts for the high recovery from slimes. The lessening yield from the latter in the latest returns probably indicates the copper influence as well as depreciation."

" From the well-known precipitating action of the metallic sulphides, it is reasonable to anticipate secondary gold enrichment about the zone of partial oxidation." †

In 1908 experiments were made with the Elmore Vacuum Concentrator which had been installed towards the close of 1907. Three units of a capacity of 150 tons per day were installed by the Elmore Proprietary. This method of treatment was discontinued after a while.

Mr. Carne paid another visit to the mine in 1908. At that time the deepest level was about 425 feet deep. "The lode had been driven on about 1,400 feet," says Mr. Carne, " and the ore was contained in two or three lenses, aggregating 700 feet in length. The average yield of gold was high, being about 8 dwt., in places reaching 12 and 16 dwt. Experiments were being made for treatment by roasting, washing, leaching, neutralising with lime, and then cyaniding. Copper was said to be about 2 per cent."

At the present time the ore is being used in conjunction with the Great Cobar ore for smelting. One of the special uses to which the siliceous ore from the mine is put is for linings for the converters, its acid nature specially qualifying it for that purpose, while its gold contents make it a valuable ore.

Development.—The workings along the Cobar gold lode consist of open cuts and four levels. (See Plate.) The open cut is about 675 feet in length, with a maximum depth of from 50 to 70 feet and an average width of about 30 feet. No. 1 level is 125 feet in depth and about 1,400 feet in length. Nos. 2 and 3 levels are 225 and 325 feet in depth, and approximately 1,750 and 1,275 feet in length, respectively. No. 4 level is 425 feet in depth and 1,500 feet in length. The average width of the lode is from 20 to 40 feet.

Preparations are now being made to sink the shaft another 100 feet, and to win the ore by means of a drive put in the slate country immediately west of the lode, with short cross-cuts therefrom at every 50 feet to the lode.

The ore has been stoped out above the 225-feet level, and the stone below that level is in the sulphide zone.

Since June, 1910, the Great Cobar, Limited, have been working the Cobar Gold Mine, and the estimate by the management of the ore " blocked out " in July, 1911, was 344,000 tons.

* Ann. Rept., 1904, p. 89. † " Copper-mining Industry," 1908, p. 215.

Production.*

Cobar Gold Mines (Fort Bourke).

Year.	Ore Raised.	Treated.		Yield.		Value.
		Crude Ore.	Tailings, Sands, and Slimes.	Gold.	Copper.	
	tons.	tons.	tons.	oz.	tons.	£ s. d.
1890 ...	......	......	......	....	......	....
1891 ...	......	600	......	150	......	....
1892 ...	......	......	......	....	......	....
1893 ...	......	......	......	....	......	....
1894 ...	......	......	......	....	......	....
1895 ...	......	......	......	....	......	....
1896 ...	......	1,474	......	509	......	....
1897 ...	......	......	......	....	......	....
1898 ...	......	......	......	....	......	....
1899 ...	......	......	......	....	......	....
1900 {	......	72,607	......	7,971·24	......	27,818 3 0
	......	......	42,294	10,382·38	......	32,320 10 3
1901 ...	......	74,349	......	18,153	......	54,767 0 0
1902 ...	......	17,621	......	9,915	......	30,539 0 0
1903 ...	......	76,307	......	32,840	......	100,916 0 0
1904 ...	......	64,700	......	27,666	......	94,943 0 0
1905 ...	......	15,176	......	10,503	......	32,750 0 0
1906 {	......	3,034	......	413	......	1,193 0 0
	......	......	5,179	2,235	......	7,026 0 0
1907 ...	1,679	......	......	....	......	....
1908 {	......	500	......	177·93	2·65	711 14 4
	......	......	......	....	......	159 14 6
	......	......	......	75	......	321 0 0
1909 {	1,450	6,558	......	2,596	......	9,733 0 0
	......	......	......	....	98·0	1,254 0 0
1910 ...	18,360	24,603	......	Included in Great Cobar Returns.	......	....
1911 ...	48,804	43,219	......			

Analysis of mine water from Cobar Gold Mine (Fort Bourke).

No. 789–11.

Analysis by Mr. W. A. Greig.

	Grains per gallon.
Lime...	4·900
Magnesia	9·331
Ferrous oxide	1·008
Alumina	0·140
Silica	2·800
Soda...	51·643
Potash	trace.
Strontia	trace.†
Cobaltous oxide	......
Nickel oxide	......
Manganous oxide	......
Copper oxide	0·070
Chlorine	47·894
Sulphur trioxide	20·089
Carbon dioxide	10·350
	148·225
Less oxygen equivalent to chlorine ...	10·790
	137·435

† Spectroscopic reaction only.

Water alkaline. The absence of cobalt, nickel, zinc, and manganese proved.

* The returns are only fragmentary, the complete information concerning production not being accessible.

Occurrence and Character of the Ore.—The Cobar Gold deposit lies in a complex fault zone at the contact of slates and argillaceous sandstones. The sandstones form the eastern, and the red slates the western, wall of the movement. The slates and sandstones are well cleaved. The dips of both sandstones and veins are high, but opposed. (Fig. 16.)

It will be seen by reference to the map that the Cobar Gold fissure is intimately related to the Chesney line of weakness, although not continuous with it. The complex Chesney line may be observed to suddenly lose its strong appearance, and to become split up into several siliceous lines arranged approximately *en echelon* with each other, while the intensity of activity apparently has passed westwards to the Cobar Gold line. Twenty-five chains north of the Cobar Gold open cut both lines may be observed to approach each other. Taking the junction of the slates and sandstones as the main line of fault, a strong and complex dislocation is suggested in the locality known as the Fort Bourke Hill. The Chesney line, which lies at the contact of slates and the sandstones, may be seen to die out to the north among the sandstones themselves, while a complication of the shearing movement has swung the sandstones round a hundred yards or thereabouts to the westward. The general shattering of the ground is illustrated in the map, where, at the northern end of the large open cut of the Cobar Gold Mine, the siliceous slates and the sandstones may be observed to have been brought across to the Cobar Gold vein proper. The map also shows that at the open cut the vein becomes lenticular in plan, while north and south of this spot it becomes narrower. The open cut is shut in on both sides by red slates, while the narrower and unpayable, but more siliceous, northern continuation of the vein occurs in the neighbourhood of the harder and coarser rock types. The outcrop of the lode in which the open cut has been excavated consisted, in

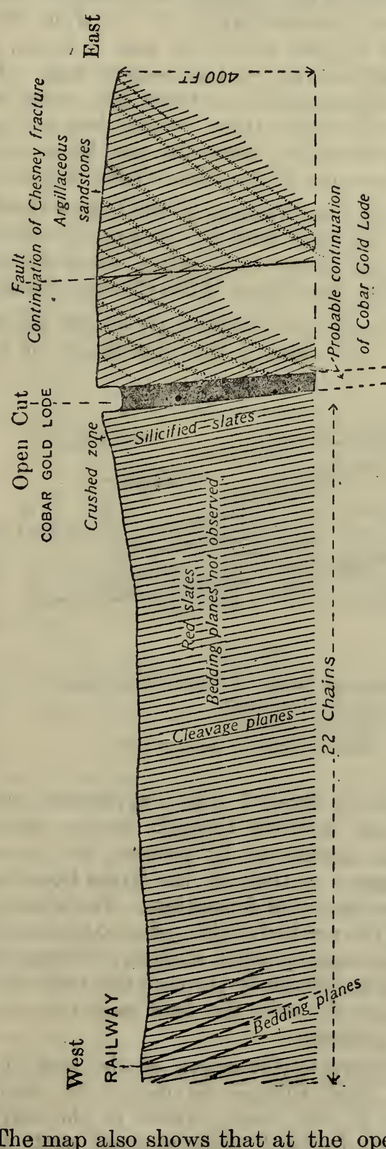


FIG. 16.

Sketch section across Cobar Gold Lode and associated country. Slates form the western wall, and sandstones the eastern wall. Both slates and sandstones are strongly cleaved. The bedding planes of the sandstones are seen dipping strongly against the dip of the lode and against the main mass of the western slate country.

the main, of siliceous slates and impure quartz. The lode dips slightly to the east, and the pay shoot has a slight pitch to the north; but each working level is approximately an orthogonal projection of the open cut floor. This was well known for the levels in the oxidised zone; but the earlier drives and workings in the sulphide zone were so carried out as to suggest that the ore body had become very poor. In June, 1910, the Great Cobar, Limited, commenced to open up Nos. 3 and 4 levels, and a body of good stone was ascertained to exist in the eastern wall. The older Company, doubtless, found it impracticable to treat this stone at a profit, and thus had not developed it. This stone, which has not yielded payable returns under ordinary gold-milling methods, has been treated profitably in conjunction with the basic ore of the Great Cobar Mine.

The mineral occurrences in the Cobar Gold Mine are similar to those of the Cobar Chesney, with this exception, namely, that the gold values in the former exceed those of the latter, while the copper values of the Cobar Gold Mine are less than those of the Chesney Mine.

Signs of powerful crushing are shown in the outcrop south of the main shaft, the rock having the appearance of a "crush" conglomerate. The peculiar lenses of silica formed in the ore body also illustrate the conditions under which the lode was formed. (See Fig. 17.)

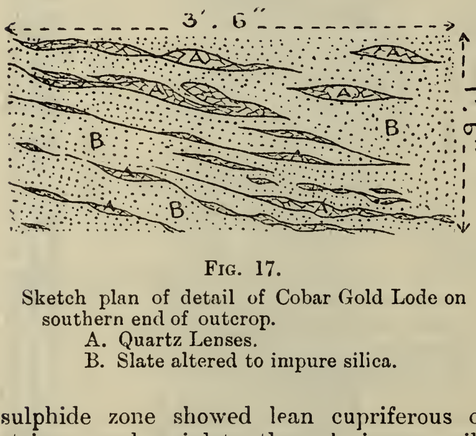


Fig. 17.
Sketch plan of detail of Cobar Gold Lode on southern end of outcrop.
A. Quartz Lenses.
B. Slate altered to impure silica.

The ore is siliceous, replacement of slates to impure quartz being the most pronounced chemical alteration.

The usual copper minerals of the oxidised zone were found above the 325-feet level. At this depth water poured in strongly from a horizontal joint.

Below the water-level, the sulphide zone showed lean cupriferous ore as chalcopyrite in blotches, strings, and veinlets through impure silica, slates, and other minerals. Pyrrhotite appears to be present, but is rare. The chalcopyrite is similar in appearance to that of the Great Cobar, and the vein belongs, doubtless, to the same period of formation. The absence of true walls, and the "tight" nature of the ore body, also point to this conclusion. Galena and zinc-blende occur in places as splashes, strings, and irregular granular patches. Although they occur indifferently through the vein matter, it is probable that here, as elsewhere in the field, the lead and zinc are later than the chalcopyrite and magnetic pyrites.

With regard to the origin of the lens of payable ore, it will be noticed that the hard siliceous sandstone of much of the eastern wall was not shattered to the same extent as the softer red slates of the foot-wall. Where this foot-wall slate opposed itself to the mass of red slate, which is sandwiched in with the sandstone belts of the hanging wall, there replacement of slate by auriferous quartz reached a maximum, and at such spot a wide zone of siliceous slate and impure quartz with copper and gold values was formed. The bedding planes of the slates possess dips of high value, and the fault planes themselves are almost vertical, therefore this lens may be expected to continue for a considerable depth below the present workings. The zone of the primary ore, however, has not yet been reached, so that although the ore lens itself may be expected to continue to great depths, nevertheless its values in copper and gold cannot be definitely known until the workings have been carried to a depth say of 200 feet below water-level.

Payable gold occurs in the oxidised zone, so also in the zone between the 425 and 325 feet levels. The ore body between the third and second levels (325 to 225 feet depth) is of high grade, but is of secondary nature. The centre of the lode appears to be harder and denser than the side portions, and an almost imperceptible grinding movement of the lode on itself has allowed of more ready descent of waters along the sides than along the central portions; and along these more shattered side portions, there appears to have been a greater enrichment than in the more central portion of the great lode. It is this ore, lying between the 325 and 225 feet levels, which is so much sought by the Great Cobar Company for smelting purposes, by reason of its gold values. The ore between the 425 and 325 feet levels is of good value, but it is also of secondary nature. Lower than this the mine has not been proved, but the value of the primary ore cannot be expected to be known until the workings have been carried down for at least an additional hundred feet.

The Peak Mines belonging to Great Cobar, Limited.

Leases.—The leases held by the Great Cobar, Limited, over the Peak include P.G.Ls. 4, 5, 6, 7, 11, and 29; G.Ls. 54, 74, 85, 138, and 149; M.P. 4; M.Ts. 3, 4, 5, 6, and 18.

The Peak Mines, worked by the Great Cobar, Limited, comprise those which occur on the southern portion of the ridge known as The Peak. (See Plates attached.) The mines worked include the Blue, the Brown, and the Conqueror Lodes.

The Peak itself is a residual of harder members of the Cobar Series, which have been crushed and faulted to a great extent. One main line of faulting may be traced along the western foot of the hillside. This is shown on the general map. Along this plane of dislocation dense hard sandstones abut against greenish-grey slates, whose planes of cleavage frequently parallel the main fault plane. Even in the siliceous sandstones the cleavage induced has obliterated the traces of the bedding planes in great measure. South of the sandstones the fault traverses slates. Here red slates occur on the western and greenish-grey slates on the eastern side. The faulting action was complicated, and appears to have consisted of one main plane of slip, supplemented by minor parallel examples east of the main dislocation.

It will be advisable to consider this fault zone a little in detail, because on the proper conception of such phenomenon the future success of mining at The Peak may be considered to hinge. It may be safely conjectured that these fault zones formed lines of communication between the deeply-seated and the less deeply-seated portions of the earth's crust in that locality. Owing to the peculiar nature of the faulting under consideration, namely, that accomplished under conditions of considerable load, it will be understood that the zone of dislocation was one of crushing rather than of one decided slip, a zone in which the faulting was distributed unevenly over a considerable width with shattering of the rocks lying between actual planes of dislocation In this way the uprising solutions are not necessarily confined to one plane; but, on the contrary, while circulating or ascending in the main planes of dislocation, they would tend to wander into the shattered country of the interfault areas, and there, under favourable conditions, to be deposited by the process of displacement.

Ore deposits of value might then be expected, both along the main planes of dislocation, and in the shattered intermediate areas.

Gold appears to be the principal mineral mined in The Peak locality, and therefore the whole of the rock belt adjoining the Great Peak Fault is worth careful prospecting. Especially is this principle applicable in the portion of the Peak where both sides of the fault, or faults, are formed of soft slates.

Take, for instance, such a faulted area as that containing the Brown and Conqueror Lodes. In these areas the whole rock-mass is shattered, and may be considered as a low-grade auriferous lode which might pay to work in a large way under present-day metallurgical methods. Instead of that, two or three richer gold viens, or "shoots," have been worked here while the mass of the low-grade material has been left.

It may be stated confidently that the shattered ground alongside of the Great Peak Fault has not been systematically prospected as much as it deserves.

An interesting point in this connection is the fact that the main plane of movement does not appear to carry the gold values to the payable extent as does the shattered country of the Hanging Wall. In prospecting the main fault planes should be considered rather as indicators, and the country thence to the east should be exploited up to, say, 100 feet from the faults. Prospecting to the west in slate country might also be profitable.

The same applies to the case of the Blue Lode, only here the zone of shattering does not appear to be nearly so wide as in the case of the Great Peak Fault. The Blue Lode Fault may be considered as one of the series of dislocations of which the Great Peak Fault is the most important member.

Fig. 18 is a sketch section illustrating the evidence yielded by an examination of the upper workings of the Brown Lode workings. No outcrops occur at this spot, the lower slopes of the hill being covered with a waste-sheet.

Other lines of dislocation occur further west. Figs. 2 and 3 illustrate the appearance of bedding suggested by the cleavage induced during the shearing action. The bedding planes here depicted stand out conspicuously simply because of the rugged nature of the outcrop, on the plain only the signs of cleavage can be distinguished.

The Blue Lode.

The lode of this name consists of two members, an eastern and a western vein. The peculiarities of the structure consists of—

(1) The anticlinal nature of the slates and sandstones which have been faulted along the line of lode;

Photo. T. F. Lean.

Great Peak—Battery and Shafts of "Brown" Lode in Foreground.

(2) The peculiar replacement action which has taken place along the planes of dislocation so as to cause the auriferous deposits to pass gradually into the slate country; and

(3) The crushed nature of the lode material in the northern portion of the leases.

Messrs. Conley and Barrass discovered the Blue Lode in 1895. "At the surface," says Mr. J. Conley, "a rich pipe of gold ore outcropped for a length of 2 feet 6 inches. For a depth of 35 feet this pipe was 20 inches in width and contained no gold at either end. Below 35 feet it became somewhat wider, and was worked down to a depth of 60 feet for an average value of 5 oz. gold per ton. At 130 feet depth the shoot dipped south."

The eastern vein was also found in 1895, but not worked until 1898.

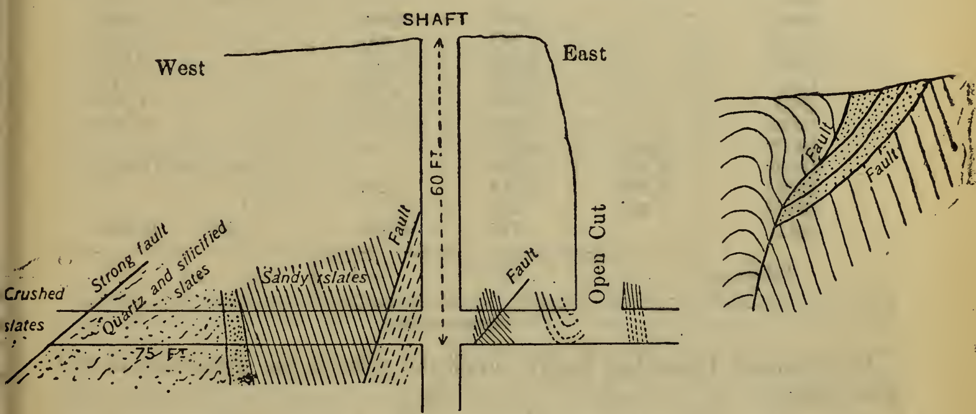


FIG. 18.

Sketch section of details of structure seen in upper workings near Open Cut along the Brown Lode. To the extreme left of sketch is shown the trace of the Great Peak Fault.

The original fissures, up which the auriferous solutions rose, appear to have been insignificant in width. Much of the ore has the appearance of country. The mobile solutions introduced silica and gold into the country alongside the fissures without even obliterating the bedding plane traces in places.

Mr. Carne* points out that—

"The presence of silver in payable proportion in some of the lodestuff is a marked feature, inasmuch as this metal is not prominent in the neighbouring lodes. Some of the rotten lodestuff, containing chloride of silver equal to about 30 oz. per ton, was used for fluxing purposes in the Cobar copper smelters.

Ordinary gold milling methods were practised at first, but in 1896 large interests were secured at The Peak by the Cobar Syndicate, and considerable prospecting then went on. In this year, 1,500 tons of stone were treated for 3,205 oz. gold. Mining operations have always been of an intermittent nature, because of the difficulty in tracing the gold shoots.

* "Copper-mining Industry," 1908, p. 210.

The approximate production of gold and silver from the Blue Lode is supplied in the accompanying table:—

Great Peak Gold Mines.

Year.	Tons raised.	Tons treated.	Yield.		Value.
			Gold.	Silver.	
			oz.	oz.	£
(Barrass and Conley's Mine.)					
1896	......	1,500	3,205	......	......
(Barrass and Conley's, and Conqueror Mines.)					
1897	......	......	......	121,251	11,762
1901	......	2,570	2,000	......	7,950
1902	......	832	657	......	2,499
1903	......	3,430	2,640	......	9,912
1904	......	3,272	1,829	......	7,118
1905	......	1,827	1,275	.....	4,945
1906	......	862	1,117	......	4,327
1907†	2,681	2,681	......	. ....	......
1908†	2,701	2,524	......	See Great Cobar.	
1909†	2,209	2,013	1,249	......	......
1910†	467	310	†	†	......
1911	......	785	2,563	8,592	10,049
Totals ...	......	......†	......†	......	......

† Incomplete returns.

Mr. Danvers Power has kindly supplied a note on the occurrence of the Blue Lode.

"*Great Peak Mine, Cobar.*—There are three separate mines that have been worked on this property, known as the "Blue Lode" at the northern end, the "Brown Lode" in the centre, and the "Conqueror Lode" to the south.

"At the Blue Lode there are two ore bodies to be seen, each averaging 6 feet wide; these approach each other as they proceed south, but diverge slightly in depth. Barrass and Conley obtained their rich gold in the early days from the western ore body, but more recently all work has been done on the eastern. The underlay of the lode is at a steep angle to the east, while the ore pitches nearly vertically to the south. The eastern ore body is made up of lenticular bodies of various sizes, some are gold-bearing, others appear to be to all intents and purposes barren. The eastern wall is fairly distinct, the lenses making on the western wall. The probability is, that the country was fractured along the present line of lode, breaking up the country into lenticular-shaped bodies which became more or less impregnated with gold. At a later period another fracture took place along the same line, forming other lenses that are not auriferous from a commercial point of view. These two systems of lenses overlap each other."

The accompanying plans and sections illustrate the character of the workings on the Blue Lode.

The deepest workings are about 240 feet from the surface, and below this level the Great Cobar Company has not succeeded in finding much payable ore.

It is difficult to assign the reason for the occurrence of the gold shoots of the Blue Lode; nevertheless, until such reason be ascertained, it will be hopeless to suggest any scientific method of exploitation of the lode. On the eastern side of the lode occur the peculiar blue slates which the auriferous veins intersect. These slates dip downhill from the Trigonometrical Station, on The Peak, to the Blue Lode. Subjacent to them are the hard and tough sandstones, which outcrop near the summit of the hill. A lode leaving the softer slates and entering these dense hard sandstones would, in all probability, lose its gold contents. A search was thereupon instituted along the lower levels of the Blue Lode for such sandstones, but only a softer rock was found, much like that nearer the surface. It thus appeared that the lode had not become impoverished by entering another class of country. The temporary loss of the gold shoots is all the more astonishing, because water level has not yet been reached in the Blue Lode.

In the Writer's opinion, the management need to take a broader view of prospecting than has been adopted here during recent years. The general pitch of the rich shoots is known, and a couple of levels, say, at 276 and 325 feet depth, respectively, might be put in, and a careful system of sampling be carried on at the same time. The gold values may also have passed away slightly east or west of the old main line, and short cross-cuts could be put in to test the so-called walls.

Brown and Conqueror Lodes.

These important gold deposits lie to the west of the Blue Lode, in a plane of movement parallel to and alongside of the main plane of dislocation at The Peak. Both lodes lie on the same strike, and the fracture in which they occur is compound. The lodes have been fairly well prospected near the surface by open cuts and vertical shafts. Excessively rich slugs of silver ore, and rich patches of gold ore, were found near the surface, and these were followed to the exclusion of the lower grade material in the intervening rocks. It is probable that such action was a mistaken one, and that the preferable method would have been to work the bodies as large low-grade deposits.

All the workings are shallow, and the deeper portions of these even were inaccessible during the visit of the Writer to Cobar.

The attached Plates illustrate the workings along the compound line of the Brown and Conqueror Lodes.

Very few records relating to these mines are extant, but a few notes which have been made from time to time by mining officials are here reproduced :—

"The Peak, Cobar (N.S.W.), has obtained the following encouraging returns from ore treated at Illawarra and at the Great Cobar Mine :—

Ore treated	205 tons.
Gold...	196 oz.
Silver	24,549 oz.

The Company are working lease 241, which is situated immediately south (on the Brown Lode) of the Great Peak Freehold, Barrass, and Conley's." *

"The Conqueror Gold-mine adjoins The Peak, and has been giving very good results for some time. The deepest level is 100 feet, where a strong body of ore occurs."†

While the Cobar report is being printed the Writer had an opportunity of examining the lower workings of the Conqueror Mine in the vicinity of

* *Australian Mining Standard*, 7th October, 1907.
† D. Milne, in Ann. Rept. Dept. Mines, 1898, p. 100.

the No. 15 Shaft. At a short distance east of the Main Fault Plane (Great Peak Fault) a zone of crushed material is found, having a direction sympathetic with that of the Main Fault. Followed along its strike this zone at times appears to become almost non-discernible in the face. The zone has yielded astonishing gold values for large tonnages treated.

Its origin appears to have been as follows:—When the Main Fault Plane was formed the Hanging Wall was shattered and allowed access to wandering and ascending solutions which, in turn, replaced the slates alongside the minor faults and planes of stress. Should the prospectors lose such a zone they should search for it *en echelon*, but never far from the Main Fault Plane. This is important.

THE OCCIDENTAL LINE.

The line of lode under consideration embraces the Occidental, the Albion, the Great Western, the Wild Duck, the Young Australian, and the Mount Pleasant Mines.

All lie along one line of powerful dislocation which is continued northwards as the Chesney Lode. The topography also suggests that these various mines form a unit, inasmuch as they lie along a low ridge of sandstones and silicified slates, which stretches from the south of the Occidental open cut to the northern point of the Mount Pleasant.

Geology.—The mines lie along a compound vein which has been formed at the junction of Silurian (?) sandstones and slates, the sandstones forming the eastern and the slates the western wall. Of these the main plane of movement is that now occupied by the wide and powerful siliceous vein known as the Gossan Lode. Notwithstanding this, the better gold and copper values appear to have been formed near to, but not in, the Gossan Lode.

The main ore bodies consist of altered slates. Other planes of movement subparallel to those of these main ore bodies occur still further east. Examples of such are the Albion, the "Indicator," of the Occidental, and the eastern vein of the Mount Pleasant Mine.

The Gossan Lode itself has resulted from the imperfect replacement of slate by silica and sulphides. In width it varies from 10 feet to 20 feet, and it offers great resistance to the agencies of weathering. West of the Gossan Lode the slate is sheared and somewhat crushed, having a silvery and schistose appearance in places. Eastwards of the Gossan Lode the slates frequently have been rendered almost flinty in places by the introduction of silica, and the quartz has commonly formed in wavy bands and as lines of lenses, some of whose shorter axes are collinear, the whole appearance suggesting an incomplete replacement of slate under conditions of considerable strain. In the sandstones the veins are narrower and more quartzose than in the slate country to the west.

The Occidental Mine.

Leases.—These include G.Ls. 1, 5, 11, 12, 13, 15, 18, 88, 102, 103, 104, 130, 136, 142, 154, and M.Ts. 2, 17, and 19, Parish Cobar.

History and Development.—The Occidental Mine appears to have been taken up originally for copper in 1872 by Ogilvie, Becker, Cornish, and others. Twelve 40-acre blocks were secured, and the Occidental was worked on one

Photo. T. F. Lean.

Occidental Open Cut (200 feet deep), looking South, showing Workings on "Big" Lode.

of the southernmost of the blocks, the rise upon which it outcrops being known as The United Hill. After sinking 100 feet vertically near the present main shaft, and cross-cutting thence for 50 feet, the attempt was abandoned temporarily. A trial crushing of 2 tons, sent to Ballarat, assayed over 1 oz. of gold per ton. About the year 1878, the mine was again exploited without success. Lack of water supply appears to have been the real cause of the difficulty here, as at other mines also along this line of lode.

The mine had a third start in 1889, with a callable capital of about £4,320. Its name was changed from that of The United to The Occidental, because of its position in the west of the State of New South Wales. The small capital was soon called up and absorbed in the erection of a ten-head battery of 650 lb. stampers, in opening up the mine, in sinking dams, and other prospecting work. Since that time the mine has been a consistent producer. Mining operations have been suspended at various times, but only because of droughts.

"This small battery, owned by the Company, crushed about 60,000 tons of ore, worth 6½ dwt., up to 1898, and paid dividends worth £4,200. At the end of 1898, a cyanide sand plant was erected to treat the accumulated sands, amounting to about 40,000 tons."

With the addition of this plant, ore worth 5 dwt. was profitable to mine and treat, and from that date the mine has gradually improved, until at the present time it has a battery crushing 4,500 tons per month, and a cyanide slimes plant treating 3,500 tons of slimes per month.

Up to June, 1908, something like 350,000 tons of ore were crushed and treated for £325,935 worth of gold. The total wages paid during this period were £163,022; and the expenditure in machinery and materials being £116,713.

"From the close of 1898 to February, 1899, during which period only a ten-head battery was used, £6,300 was paid in dividends; and up to February, 1905 (a further period of six years), with the addition of the cyanide sand plant, a further sum of £17,850 was paid in dividends."

"From February, 1905, to October, 1908, a further sum of £27,300 was paid in dividends, thus making a grand total to date (1908) of £51,450 paid in dividends on a capital amounting to only £4,320.

From paying £6,300 in ten years, the improvements have brought the dividends up to £12,600 for the year; and, to take another comparison, at one time ore worth 6½ dwt. (£1 7s. 7d.) paid a profit, whereas now, ore worth 4 dwt. (17s.), or 10s. 7d. less, is equally as profitable although more difficult to mine."—[Extract from notes written in 1908 and supplied by Mr. John Leah, Legal Manager. It must be distinctly understood that these figures do not apply to the present conditions, the oxidised zone of which the legal manager speaks having all been removed, and sulphide ore only being left.]

The mine is worked by means of an open cut and five levels. The open cut is 208 feet in depth and possesses very steep sides. The northern cut is about 480 feet long on its western side; the southern cut is now continuous with the northern one, but is not so wide. Its length approximates to 172 feet, thus giving a total length of about 650 feet for the great open cut. The ends are not vertical and are not so wide as the central portion, owing to the lenticular nature of the payable ore body, the widest portion of the lens being in the neighbourhood of the centre of the open cut. The maximum width of the open cut at the surface is about 100 feet; the eastern wall is 10 feet higher than the collar of the main shaft, and the same wall has been taken down on a batter to about 50 feet in width to fill the stopes back of No. 2 level. The accompanying Plates illustrate the general appearance of the open cut.

The main shaft is 12 feet by 4 feet 6 inches in the clear and has three compartments.

The levels are five in number and are at depths approximately of 140, 240, 340, 440, and 540 feet respectively below the surface.

No. 1 *Level* (140 feet).—The lodes lie to the east of the main shaft, and cross-cuts have been put in east from the main shaft to all the levels, as the lode underlays slightly to the east. The cross-cut from the middle of the platt to the east wall of the Gossan Lode is 70 feet long; thence the north drive extends for a distance of 408 feet, and the south drive for a distance of 340 feet. The open cut has now been carried 50 or 60 feet below the No. 1 level. At 150 feet depth the average length of the northern open cut is 260 feet, and its width in the northern end 65 feet at the same level. A branch of the main open cut occurs to the east of the large slate "horse" in the Big Lode. Drives and cross-cuts have been run northwards to the Great Western shaft from the east side of the open cut. A drive along the lode at this level to the shaft under consideration is 160 feet in length.

No. 2 *Level* (240 feet).—The length of the cross-cut from the shaft to the east wall of the Gossan Lode is 77 feet. The north drive is 108 and the south drive 102 feet from this point. On the Big Lode the north drive on the east side is 250 feet in length. The south stope under the south cutting has a length of 115 feet. The distance from the main cross-cut to the south end is 212 feet. A drive 117 feet in length has been put in along the lode to the Great Western shaft. Cross-cuts have also been put in from the eastern side of the second level to connect with the shaft of the Great Western and to intersect the Albion Lode.

No. 3 *Level** (340 feet) is on the Big Lode, the largest of the Occidental ore bodies. From the footwall to the eastern wall, as worked, the width was 57½ feet. High stopes exist in places. The south drive is about 120 feet in length. On the east side it has been put in 271 feet from a point along the main cross-cut. On the east side the south drive is 90 feet long.

No. 4 *Level*† (440 feet).—Length of cross-cut through Big Lode 70 feet. No. 1 drive north at 106 feet in main cross-cut is 112 feet in length. No. 2 drive north at 132 feet in cross-cut is 228 feet long. No. 3 drive north 74 feet, No. 1 drive south 133 feet, No. 2 drive south 63 feet, and No. 3 drive south 103 feet, in length.

No. 5 *Level* † (540 feet).—The length of the cross-cut from the shaft to the east side of the Big Lode is 180 feet. The No. 1 drive, at 109 feet along the cross-cut to the north, is 85 feet in length, No. 2 drive north 290 feet, No. 3 drive north 45 feet, No. 1 south drive 68 feet, and No. 3 south drive 95 feet in length.

The machinery includes a Dodge Giant Stone-breaker (15 in. x 9 in.) sixty head of stamps, forty being 800 lb. each and twenty being 700 lb. each, a Raff or Tailings' Wheel, 25 feet in diameter, driven by Tandem Compound Engine; 2 Babcock and Wilcox Boilers, 96 and 150 h.p., and other boilers and engines.

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* These measurements are entered up here as for September, 1911.
† Measurements up to September, 1911.

Photo. T. F. Lean.

Occidental Open Cut, looking North, Sandstone Wall to Left, "Gossan" Lode to Right.

The following were the expenses* for the half-year ending 29th July, 1908, as supplied by the legal manager:—

	£	s.	d.	Per ton. s.	d.
Stone-raising [24,856 tons raised]—					
Wages	4,242	4	6	3	11·72
Explosives	608	12	1	0	5·87
Timber	43	19	5	0	0·42
Firewood	144	19	10	0	1·4
Candles	62	2	7	0	0·6
Iron, &c.	72	9	11	0	0·7
Crushing—					
Wages	1,283	19	3	1	0·4
Firewood	1,061	16	3	0	10·25
Shoes and dies	207	2	8	0	2
Screens	129	9	2	0	1·25
Oils, &c....	217	8	9	0	2·1
Wages—					
Blacksmiths, Carpenters, Labourers	£690	11	6	0	6·66
	£9,464	15	11	7	7·37

Veins, Character, and Occurrence of Ore.—It has already been pointed out that the Occidental Lode is compound in nature, consisting of the "Gossan Lode" to the west, with a narrow "horse" or zone of unpayable altered slate to the immediate east of the Gossan Lode, and a large lens of ore to the east of this having a length of several hundreds of feet and a maximum width of about 80 feet, the central portion of the ore lens being composed of a "horse" from 8 to 12 feet in width. The body is known as "The Big Lode." Beyond this again, to the east, lie the "Indicator" and Albion veins. All the veins are subparallel, and they possess very steep dips. The Plates give a general idea of the association of the veins and of their relations, both to one another, and to the sandstone country on the east and the slate on the west.

A limestone or calcite "breccia" is intersected by the main shaft at both the fourth and the fifth levels. The "breccia" has not been found in the upper levels, as it appears to lie west of the shaft nearer the surface. The occurrence is not of the nature of a true breccia, but consists of a shattered or strained mass of slates which has been so penetrated and replaced by calcitic solutions in the vicinity of the incipient cracks in the original rock as to assume the appearance of a true breccia. The eastern wall of the limestone and slate mass is much crushed, and both galena and zinc occur in joints in the calcitic mass.

The Gossan Lode lies to the east of the shaft (see attached section), and the space between this lode and the so-called "breccia" is occupied by a mass of well-cleaved slate.

The Big Lode.—The widest portion of this lode lies due east of the main shaft, where, exclusive of the "horse" of altered slate, it has been worked for a width of about 43 feet along the upper levels. Its length to the north of this maximum width is about 200 feet and its length to the south rather less than 100 feet. To the south and the north it dies out in wedge-form.

Several important points may be noted in connection with this lode. In the first place, there are no distinct walls by which the lode can be distinguished readily from the country, and the recognition of the lode material here comes only as a result of continued and careful observation. The lode is of highly altered slate—so altered as to resemble chert or felsite in places. Silicification has been the commonest form of alteration, and the

* These expenses were incurred in mining oxidised ore; the present costs in the sulphides are greater.

peculiar forms assumed by the veinlets and lenses of quartz suggest that the introduction of silica took place under conditions of great pressure. The quartz continually occurs in wavy and ribbon-like patterns, or as small lenses whose shorter axes are collinear. Unlike the calcite mass to the west, which is strongly marked off from the slate country to the east by a wall of weak decomposed material, the Big Lode appears to have been welded or cemented into the country to such an extent by silica that the ground stands without support when opened up.

In the second place, the so-called "elvans," or bands of chert, resulting from the silicification of slate, and which commonly occur in the western portion of the Big Lode, appear to be favourable indications of gold. These "elvans" resemble the "Indicator" of Mount Drysdale in general appearance.

In the third place, a thin belt of magnetite and slate veins is known to occur on the immediate east of the Big Lode. Apparently it has not been found at a distance of less than 190 feet north of the main cross-cut from the shaft on Nos. 4 and 5 levels. At this point it is tangential to the tapering lens of the Big Lode, and its direction is practically north and south, while that of the Big Lode is from 15° to 20° west of north. It is at the point where the Big Lode proper is seen to pass away decidedly to the west of north that the magnetite veins may be seen "making," and then maintaining, a northerly course. Where observed by the Writer on No. 5 level, the magnetite veins were always narrow, the largest individual being only 6 inches in width, and the total width of the several veins in the face, including the intermediate slate, not exceeding 2 feet 6 inches or 3 feet. Associated with the magnetite along its western wall, schistose material was found, containing large admixtures of bismuth and pyrites. Both the bismuth and magnetite veins are rich in gold values. In spite of the excessive narrowness of the magnetite series, it is so rich as to be called the "Indicator." It is also known as the "Jack Johnson," owing to a curious association of ideas. In the oxidised zone the magnetite had been replaced by limonite, and when it was first struck in the drives below water-level its mineral character was not at once recognised. Very high values of gold, however, were obtained from it. At that time (1908) a coloured American pugilist had just won the World's Championship for heavyweight boxers, and since the strange mineral found at that time in the Occidental was dark, heavy, and valuable, it was called "Jack Johnson" by the local miners.

Over a distance of about 60 feet in the No. 2 drive north along No. 5 level, the Writer secured several specimens of the "Indicator" at random, some from the walls of the drive 60 or 70 feet from the face, and some from the working face showing in September, 1911. Three assays of this stone were made at the Departmental Laboratory, with the following results :—

[3776-11.] Magnetite ore (siliceous), 260 feet north of shaft, 540 feet level—
Gold—33 oz. 17 dwt. 7 grs. per ton.
Silver—1 oz. 17 dwt. per ton.
Copper—A trace (less than 0·25 per cent.).

[3247.] Pyritous magnetite-bearing siliceous schist, from "The Indicator," 200 feet north of shaft, 540 feet level—
Gold—27 oz. 0 dwt. 2 grs. per ton (free gold).
Silver—1 oz. 14 dwt. 20 grs.

[2958.] Quartz with magnetic iron ore, and sulphide of lead and bismuth, 200 feet north of shaft, 540 feet level—
Gold—1 oz. 6 dwt. 3 grs. per ton.
Silver—10 dwt. 21 grs. per ton.
Lead—2·10 per cent.
Copper—0·67 per cent.
Bismuth—14·40 per cent.

Photo. T. F. Lean.

Shaft and Cyanide Works, Occidental Mine.

These values are doubtless far above he average for "The Indicator," but they were selected at random by the Writer, and are here recorded as such.

In the fourth place, the Albion Lode, which was worked in the sandstones to the north and east of the open cut, has not been found to continue as far south as the Big Lode itself.

In the fifth place, silicates of iron and pyrrhotite occur in the Big Lode, but no zinc-blende has been reported from this portion of the lode ; whereas, on the other hand, it has been found in the calcite mass to the west.

In the sixth place, the copper values of the Occidental are almost negligible.

In the seventh place, the size of the Big Lode does not appear to have appreciably diminished at the (Plate) greatest depth reached (540 feet). Attached is a copy of the assay values found in the cross-cut *at the 540 feet.

The "horse" in the Big Lode represents a portion of altered slate, which does not contain sufficient gold values to pay for its extraction.

The Big and the Gossan Lodes thus appear to be the same age as the Greac Cobar Lode, while the decomposed calcite mass to the west, with the traces of galena and zinc-blende, appears to be of the same age as the west wall of the Great Cobar Mine, the Cobar Peak Silver-mine, and the younger portions of the C.S.A. and Tinto lodes.

In attempting to arrive at quantities of ore reserves, one can only be guided by the methods of working adopted by the Occidental Company. Up to the end of August, 1911, about 560,000 tons of ore had been won from the mine. This tonnage came practically from the upper 340 feet, and it might thus be thought that between each succeeding level of 100 feet about 175,000 tons of ore could be expected. Thus, between the 540 and 340 feet levels, one might expect from 300,000 to 350,000 tons of ore, on the assumption that the ore bodies maintained their width and values with depth. The policy of

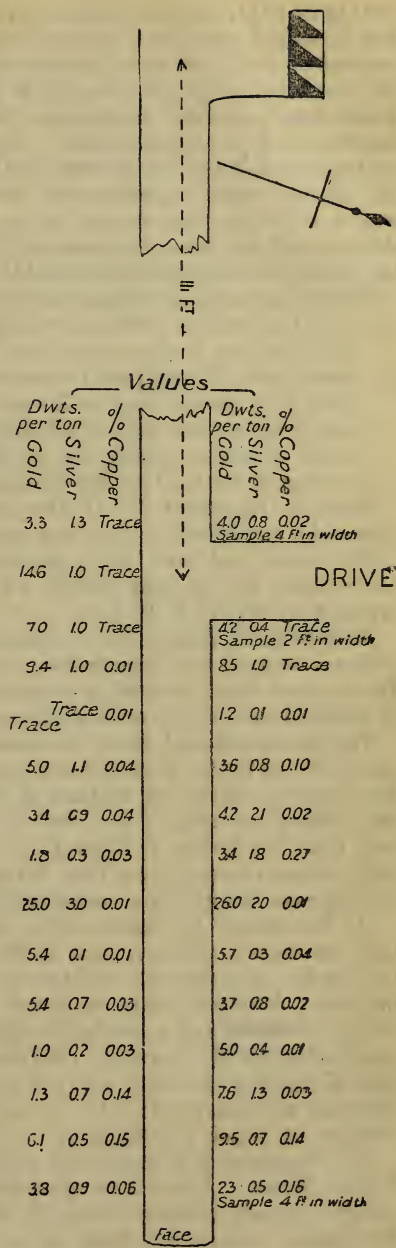

FIG. 19.

Assay Plan in cross-cut from main shaft on No. 5 Level (540 feet), Occidental Mine ; reproduced from assay plan supplied by Occidental Gold Mining Company.

* This cross-cut is 200 feet south of the point at which the magnetite vein or "Indicator" makes its appearance.

mining in 1911, however, indicated that a certain proportion of the lode would not be mined below the 340-feet level. Only the richer veins were being worked in 1911, and it is probable that only about 150,000 tons of ore will be won between the third and fifth levels, unless this policy be altered. It would seem preferable to continue the working of the Occidental Mine on a large scale, if at all practicable. Up till the present time it has paid well, by treatment of the whole width of the ore body. Inspector Godfrey pointed out that, to work deposits such as the one under consideration in a small way was "worse than useless, because it not only does not pay, but destroys the value of the mine, by removing the better class ore, and thus rendering the whole less amenable to profitable treatment."*

Referring to the Occidental Mine itself, Inspector Godfrey wrote :—

> "The success of this mine is a strong argument in favour of economic handling on a very large scale. When the mine was worked with a small mill, it only paid to search for and treat the rich patches. Now that they have a large mill, supplemented by a large cyanide plant, they can treat all the lode stuff, and pay dividends; and the success of the mine is about equally due to cheap mining on a large scale, and the saving of the gold by the cyanide process."†

Since the reports of Mr. Godfrey and Mr. Carne, the oxidised ore of the lens under consideration has been exhausted, and the problem of the payable extraction of gold from the sulphide ores has had to be faced. The following notes upon the present process of recovery are based upon information supplied by Mr. T. F. R. Lean :—

Metallurgical Notes.—The present method of treating the ore is by ordinary battery and cyanidation, with Moore Filter Process for the slimes. The ore now being treated is combined in the form of sulphides in a gangue of siliceous slate and chert containing magnetite.

The ore is trucked from the brace to a Giant Rock-breaker; thence it is conveyed partly by trucking and partly by gravitation to the battery bins. The battery consists of 60-head of stampers, the copper plates belonging to the battery are from 4 to 5 feet in length, and after traversing these the pulp from the battery is treated with two Wilfley and four Card tables. The pulp is then elevated by a Raff Wheel, and conveyed by gravitation to sand settling pits, the overflow containing the slime passing to slime pits.

(1) *Treatment of Sands.*—The sands are trucked into vats, of which there are nine in number, each 25 feet in diameter, and of a capacity of 100 tons each. A 4 per cent. solution of cyanide is then run on to the sands in the vats; fourteen hours completes this preliminary treatment; then this charge is run off and a similar charge of cyanide solution is put on, which is returned by air lifts during a period of three days. A second treatment consists of treating the sands with a ·1 per cent. solution for a period of five days. The vats are then emptied by bottom doors into trucks. The sands are then elevated by winch and dumped.

(2) *Treatment of Slimes.*—The slimes are trucked from the slime pits to a Vortex Mixer. About 2 lb. of slaked lime per ton are added to slimes here, and the cyanide solution enters the Mixer from ·35 to ·40 per cent. strength. The mixed slimes are then elevated by a 3-inch centrifugal pump into galvanized-iron agitating tanks; agitation takes place by centrifugal pumps and air; thence the slimes pass into V-shaped building tanks, into which a filter basket, consisting of eighteen frames covered with cotton-duck is dropped and connected with a vacuum pump. A period of ten minutes is necessary for the filter basket to become loaded. The basket is then elevated by an

* J. E. Carne, "Copper-mining Industry," 1908, p. 204. † Ann. Rept., 1900, p. 102.

electric crane and dropped into a weak cyanide solution and washed by sucking the solutions through the slimes for sixty minutes with a vacuum pump. The basket is then lifted and conveyed by electric traversing gear to a discharging hopper. The vacuum pump at this stage is disconnected, and an air-pipe connection is established with the filter basket. Air is then forced in, which detaches the cakes of slime and causes them to fall into trucks below the hopper. Thence they are cut up with a centrifugal pump, and conveyed to the residue heap.

The future policy is to battery crush, then slime all battery pulp by means of Krupp tube mills, and treat with Moore filter process. A recovery of at least 85 per cent. may thus be expected. The plant should be installed early in 1912.

The treatment of sands has apparently been abandoned since early in the year 1912.

In one of the Appendices to this Report, the question of smelting the Occidental ore is considered.

The production of the mine is here presented ; the returns are incomplete :—

Occidental Gold-Mine Returns.

Year.	Ore Raised.	Treated.	Yield—Gold.	Value.	Remarks.
	tons.	Tons crushed.	oz. dwt. grs.	£	
1889	....	690	718 3 18	....	Ann. Rept. 1889, p. 126 (Min. Registrar's).
1890	....	140	118 10 0	474	,, ,, 1890, p. 130 ,, ,,
1891	....	2,534	1,555 0 0	6,207	,, ,, 1891, p. 140 (Warden's).
1892	2,800	2,800	841 0 0	3,488	,, ,, 1892, p. 21 (Min. Regist. & Ward.).
1893	....	4,400	1,090 0 0	....	,, ,, 1893, p. 24, ,, ,,
1894	....	....	....	....	
1895	....	8,647	1,492 0 0	....	,, ,, 1895 ,, ,,
1896	....	9,900	1,651 0 0	....	,, ,, 1896 ,, ,,
1897	....	....	....	....	
1898	....	....	....	....	
1899	....	....	3,703 0 0	....	,, ,, 1899, p. 100 (Inspector of Mines).

<table>
<tr><th>Year.</th><th colspan="3">Treated.</th><th>Yield.</th><th>Value.</th><th>Total Value.</th><th>Remarks.</th></tr>
<tr><td></td><td>Crudes. tons.</td><td>Tailings. tons.</td><td>tons.</td><td>oz. dwt.</td><td>£ s. d.</td><td>£ s. d.</td><td></td></tr>
<tr><td>1901</td><td>28,076</td><td>....</td><td>....</td><td>3,352 17</td><td>14,990 0 0</td><td>....</td><td>Battery. (Records in possession of Chief Inspector of Mines.)</td></tr>
<tr><td></td><td>....</td><td>22,215</td><td>....</td><td>3,079 0</td><td>9,887 0 0</td><td>....</td><td>Tailings.</td></tr>
<tr><td>1902</td><td>6,654</td><td>....</td><td>....</td><td>1,144 0</td><td>3,700 0 0</td><td>....</td><td></td></tr>
<tr><td>1903</td><td>45,567</td><td>....</td><td>....</td><td>8,800 0</td><td>34,200 0 0</td><td>....</td><td></td></tr>
<tr><td></td><td>Ore.</td><td>Sands.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1904</td><td>47,066</td><td>....</td><td>....</td><td>5,005 2</td><td>18,450 0 0</td><td>....</td><td>Amalgamation.</td></tr>
<tr><td></td><td>....</td><td>34,000</td><td>....</td><td>3,870 9</td><td>15,250 0 0</td><td>....</td><td>Cyanidation.</td></tr>
<tr><td></td><td>Crudes.</td><td>Tailings.</td><td>Slimes.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1905</td><td>44,089</td><td>....</td><td>....</td><td>4,150 0</td><td>16,164 0 0</td><td>....</td><td>Amalgamation.</td></tr>
<tr><td></td><td>....</td><td>34,300</td><td>....</td><td>4,544 0</td><td>14,924 0 0</td><td>....</td><td>Cyanidation.</td></tr>
<tr><td></td><td>....</td><td>....</td><td>7,500</td><td>1,015 0</td><td>2,658 0 0</td><td>33,746 0 0</td><td></td></tr>
<tr><td></td><td></td><td>Sands.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1906</td><td>46,258</td><td>....</td><td>....</td><td>4,821 0</td><td>17,765 0 0</td><td>....</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">63 037</td><td>7,030 0</td><td>25,878 0 0</td><td>43,643 0 0</td><td>(Returns from Mine Records.)</td></tr>
<tr><td>1907</td><td>45,719</td><td>....</td><td>....</td><td>3,959 0</td><td>14,662 0 0</td><td>....</td><td></td></tr>
<tr><td></td><td>....</td><td>....</td><td>27,600</td><td>8,449 0</td><td>28,500 0 0</td><td>43,162 0 0</td><td></td></tr>
<tr><td>1908</td><td>51,103</td><td>....</td><td>....</td><td>4,479 16</td><td>15,338 1 0</td><td>....</td><td></td></tr>
<tr><td></td><td>....</td><td>36,000</td><td>....</td><td>5,606 0</td><td>19,390 2 0</td><td>....</td><td></td></tr>
<tr><td></td><td>....</td><td>....</td><td>40,771</td><td>3,599 0</td><td>22,908 16 0</td><td>57,636 19 0</td><td></td></tr>
<tr><td>1909</td><td>49,557</td><td>....</td><td>....</td><td>5,428 0</td><td>18,911 0 0</td><td></td><td></td></tr>
<tr><td></td><td>....</td><td>33,000</td><td>. ..</td><td>5,926 0</td><td>20,243 0 0</td><td>66,404 0 0</td><td></td></tr>
<tr><td>*1910</td><td>49,784</td><td>....</td><td>....</td><td>4,356 0</td><td>14,421 0 0</td><td>....</td><td></td></tr>
<tr><td></td><td>....</td><td>33,000</td><td>....</td><td>5,878 0</td><td>16,775 0 0</td><td>....</td><td></td></tr>
<tr><td></td><td>....</td><td>....</td><td>22,930</td><td>4,581 0</td><td>13,825 0 0</td><td>....</td><td></td></tr>
<tr><td></td><td>....</td><td>....</td><td>....</td><td>....</td><td>690 0 0</td><td colspan="2">other products disposed of.</td></tr>
<tr><td></td><td></td><td></td><td>....</td><td></td><td></td><td>45,711 0 0</td><td></td></tr>
<tr><td>1911</td><td>Ore raised 38,905</td><td>201 con. 33,800 san.</td><td>12,145</td><td>....</td><td>....</td><td>43,555 0 0</td><td></td></tr>
<tr><td>Totals †</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

* Returns for this year from Ann. Rept. for 1910, p. 11. † Returns incomplete.

With regard to the future of the Occidental Mine, it may be stated that there is every reason to believe that the Big Lode and the "Indicator" will continue for a considerable depth below the lowest level (540 feet) yet worked. The geological associations point to this conclusion, for the lodes have been formed in crushed slate at the contact of sandstones and slates. All the evidence available points to the conclusion that the slate of the footwall and the sandstone of the hanging-wall are of considerable thickness. A slight buckling and dragging of the hanging-wall on the footwall with crushing of the contorted slates has probably occurred at this point, and by the replacement of the slates the ore lenses appear to have been formed. This is suggested by the local bending of the rock dips into the plane of the lode, the lenticular nature of the large ore bodies, the cherty nature of the slates, and the absence of true walls. If in a discussion such as the present the slate series had been ascertained to be only of inconsiderable thickness, and if, moreover, such narrow slate series were known to be underlain by rock types such as coarse siliceous conglomerates, then one might have serious misgivings as to the commercial value of the ore body at the depth at which the kindly slates should cease and the coarse siliceous types be entered. But in the case of the Occidental the slates are of great thickness, and there is no reason to believe that the lode will materially diminish in values, for depths much greater than at present known, unless indeed the zone of secondary gold ore has not yet been passed. With respect to this last consideration, the presence of the magnetite indicator *underlying* the oxidised zone would suggest that the ore along the fourth and fifth levels is, in the main, primary. The presence of the cherts also, on the fifth level, to the exclusion of almost all other minerals, with the exception of the magnetite, bismuth, and quartz, also suggests its primary nature. It must not be forgotten, however, that the present workings are only 200 feet below water-level, and that in the Cobar district it is unsafe to rely on meeting primary ore only at such a shallow depth below water-level as 200 feet.

The possibility of smelting an ore such as the Occidental is considered in Appendix III.

The Great Western and the Albion.

These mines are now owned by the Occidental Company. The underground workings of all are connected. They lie along the same zone of crushing as the Occidental, and adjoin it immediately to the north. The height of the low ridge known as the United Hill is the same through the Great Western property as through the Occidental. The summit and eastern portion of the ridge consist of argillaceous sandstones; the western portion consists of crushed slates and lode materials as in the neighbouring Occidental. Prospecting by means of shaft sinking, driving, and cross-cutting in the zone of crushing has been carried out. The more important of these prospecting operations are shown on attached Plates. Quite recently a shaft has been sunk for a depth of about 300 feet in the northern portion of the property, and at the junction of the sandstones and slates. Nothing of importance, however, appears to have been disclosed by this prospecting work.

Information concerning the development, history, and production of both the Great Western and the Albion Lodes is meagre. Most of the records of these mines appear to have been lost or destroyed, and a search through the Departmental Records discloses little beyond that already contained in

Mr. Carne's "Copper Mining Industry," and these are here reproduced because of their value in calling attention to the necessity for prospecting the zone of crushing extending from the Occidental to the Chesney Mines.

Mr. Carne points out [1908, p. 206] that the Phœnix, Mount Pleasant, the Young Australian, the Great Western, and the Occidental Mines occupy a very strongly impregnated body of country, averaging more than 30 feet in width. "In the Cobar-Chesney, at the north end, it has been exposed in the workings for a length of over 800 feet, with an average width of 35 to 40 feet. In the Occidental, at the extreme south end, it proved equally strong in the extensive open-cut workings, which reached a depth of 130 feet.

"Only in these two mines has the full width of the lode been attacked. The intermediate mines have confined operations to limited patches of richer stone instead of utilising the whole on a scale commensurate with its extent. "Thus, in the Great Western Mine, to whose southern boundary the open-cut workings of the Occidental have been extended, the method of exploitation called forth the following strong statements from Inspector Godfrey and Schloesser.

> "This mine has been alternately at work and under suspension throughout the year, but at no time has it been worked on an extensive scale, and all the work has been confined to a small reef on the east side of the main lode. This main lode is the same as that worked so successfully a few hundred feet away by the Occidental Company, and it seems incomprehensible how a mine should leave its main ore-body unproven and undeveloped when the very next mine is paying dividends."*
>
> Inspector Schloesser stated that "The Great Western has proved the extension of the Occidental ores into its ground by a cross-cut to the west from the 400-feet level. A large amount of dead work is, however, necessary before such low-grade material can be worked by underground stopes on anything like an adequate scale. After being idle for eleven and a half months the mine is now in the hands of tributors, who can hardly be expected to improve the mine."
>
> "Possessing practically the same ore as the Occidental is now profitably exploiting, and, in addition, possessing the Albion lode, that was in the past highly payable, there seems no reason why, if worked on a large scale, this mine should not give profitable returns."†

The Albion Lease was taken up within a day or two after the Occidental, in 1889, and in fact all the various claims between the Occidental and the Chesney are said to have been taken up within a space of three months after the Occidental.

It is difficult to arrive at the output of this mine to date. For long periods practically little was done save following the rich shoot in the Albion lode. The first available record shows a yield of 106 oz. from 180 tons; depth 40 feet, lode 4 feet thick.

From records in Mr. T. E. Farquhar's possession, the Albion produced £1,180 in dividends during the period 1894.

"In 1895 a record of 951 oz. from 870 tons,‡ equivalent to about 21½ dwt. per ton. Patches of even richer stone were obtained where evidence of leaching and redeposition in the metallic state was afforded by leafy

* Ann. Rept., 1896, p. 36. † *Ibid.*, 1902, p. 79. ‡ *Ibid.*, 1900, p. 12.

films of metallic copper intercalated in the laminæ of the ferruginous slate forming the lode stuff. This class of ore was sorted from the battery stuff and despatched to the Dapto Smelting Works. The following returns from this ore were taken from the *Australian Mining Standard* of 11th August, 1898, and a later issue :—

9 tons 15 cwt. yielded—gold, 5 oz. 11 dwt. 8 grs. per ton; copper, 3·1 per cent.

14 tons 13 cwt. yielded—gold, 4 oz. 2 dwt. 3 grs. per ton; copper, 2·1 per cent.

There appears to be no output from this mine during 1901–4.*

Golden Crown.—Adjoining the Occidental to the north, and taken up a week later than the Occidental. Prospecting campaign was unsuccessful, and the land has since been absorbed by a stronger company.

The Cobar Copper Company.—*Leases*: G.Ls. 4, 6, 7, 16, 19, 20, 81, and 93. M.L. Portions Nos. 24, 25, and 28, Parish Cobar. The mines worked by this Company lie along the same line of the lode as the Occidental, the Great Western, and the Chesney. The mines now embraced under the one name were formerly worked under the names of the Wood Duck, the Young Australian, and the Mount Pleasant. The Wood Duck has the most southerly shaft; the Young Australian lies to the immediate north of this; and the Mount Pleasant covers the continuation northwards of the Young Australian line.

The main line of lode is the westernmost yet discovered, and the eastern lode lies about 160 feet easterly of this in the Mount Pleasant block. This eastern lode is rather narrow, and occurs in the sandstones. It appears to be a southern continuation of one of the eastern lodes of the Chesney. Important lodes in the Cobar field rarely occur in the sandstones, but, on the other hand, are found almost wholly in zones of crushed slate at or near their contacts with harder and coarser rocks.

The Wood Duck.—The Wood Duck shaft is about 155 feet in depth, and is connected with the Young Australian shaft by means of a drive at a depth of 155 feet. The shaft was sunk alongside of the Gossan lode at the surface, and at a depth of 155 feet the same lode is found a few feet to the east of the vertical Wood Duck shaft.

The accompanying note by the late Mr. W. H. J. Slee, Chief Inspector of Mines, in the Annual Report for 1893 (p. 65), is about the only official record of this mine.—

> "Adjoining this [two leases north of the Albion] is the Wood Duck Mine (A. Mallot, Hunt, and party). This party has lately crushed 107 tons, yielding 88 oz. 11 dwt. of smelted gold. The width of the lode taken for crushing purposes is 4 feet, and the deepest level 34 feet. About 30 tons more are likely to be crushed before the end of this year."

The Wood Duck shaft is being used at present for haulage purposes by Snelson's tributing party in the Young Australian.

The Young Australian.—It is reported that a Mr. Thomas Parras—[Barrass (?).—E.C.A.]—first discovered gold about the year 1891. Silver, copper, and lead were also obtained at a later date. This mine was worked by a deep open cut at one time. The large siliceous lode, known as the Gossan

* "Copper-mining Industry," 1908, pp. 206–207.

Lode, forming the eastern wall of the open cut. This open cut appears to have exceeded 100 feet in depth, but is now partly filled with mullock. The gold occurred in a crushed and otherwise altered mass of slates, lying immediately to the west of the Gossan Lode. A "slide," dipping to the south, at an angle of about 45 degrees, commenced in the open cut. According to experienced miners, the gold did not follow this slide, but occupied two subparallel zones in the crushed slates. The oxidised stone in this, the northern portion of the property, was comparatively free from copper, and cyanidation of the tailings was practicable.

It was estimated that about 27 per cent. of the gold contents was extracted in the stamper battery, and 90 per cent. of the remainder by cyanidation, additional evidence of the importance of the latter process, and the seriousness of any obstacle, such as slight copper contamination, vitiating its application.*

In 1896 machinery was erected, and 1,900 tons of siliceous ore were crushed for a return of 1,003 oz. gold.† Copper was met with in 1897, and it was at once understood that difficulty would be experienced in extracting gold from the lower levels. [In the same year (1897) copper was met with for the first time in the Berribungie, the Great Western, and the Occidental.] In 1898 a cyanide plant was added, a 15-head battery was also in use, the machinery being valued at £6,000. It would seem, however, that the results obtained were very disappointing, although the reason assigned was an insufficiency of capital to develop the mine.‡ In 1901 successful prospecting was reported; nevertheless, in 1905, no important results had been disclosed, although the main shaft had been carried down to a depth of 300 feet, and drives had been put in north and south of the shaft at depths of 155, 200, and 285 feet. Prospecting was still being carried out in 1906, but no work was carried out during the years 1907, 1908, and 1909.

In October, 1910, the mine was let on tribute to Snelson and party, who at once commenced to prospect the lode in the vicinity of the Wood Duck shaft, at the 155 feet level. Good copper, in the form of carbonates, red oxide, and black sulphide, was known to exist for a length of from 50 to 60 feet and several feet in width immediately east of the Gossan Lode. A winze, 100 feet in depth, was sunk on the lode, and drives were put in at this depth to prove the copper values. At least 60 feet length of good copper ore has been opened up, the minerals being characteristically native copper, red oxide, and black sulphide. Water level was met at the bottom of the winze. The ore is very siliceous, and is an expensive one to smelt because of the excess of silica over iron.

"From a tribute in the Young Australian portion of the mine, 55 tons of ore were raised and sold to the Great Cobar, Limited, the gross value of the metallic contents being £120."*§

The assay value of one parcel of 70 tons from this winze sold to the Great Cobar, Limited, was as follows :—

Copper	7·69 per cent.	Oxidised ore.
Iron	8·00 ,, ,,	
Insoluble	66·20 ,, ,,	
Alumina	1·50 ,, ,,	

The total amount of the copper won during the prospecting operations of the present tribute is estimated at 43½ tons from 499 tons of ore by Mr. P. Snelson.

* J. E. Carne, "Copper-mining Industry," 1908, p. 207. † Ann. Rept., 1896. ‡ Ann. Repts., 1898-1900.
§ Mr. Inspector Polkinghorne's report, Ann. Rept., 1910, p. 96.

Mount Pleasant Mine.—A Mr. Pierce is said to have pegged out the land now embracing the Mount Pleasant in 1884 or 1885. Gold was found at this period. At a later period copper, silver, and lead also were found.

The gross value of the metals obtained from this mine up till 1901 is estimated at £7,300.

In this mine signs of copper came in at a depth of about 160 feet. The carbonates, red oxides, and black sulphides thus met with changed to yellow sulphide at a depth of about 180 feet from the surface.

The Mount Pleasant Mine was closed down during the visit of the Writer to Cobar in 1910, and the lower levels of the Young Australian are under water. Notes made by Mr. Carne at various times are here reproduced:—

> "Published records furnish very scant information concerning operations in this mine. Such as are available indicate copper as the chief product. In 1895, 469 tons of oxidised lodestuff appear to have been treated for a return of 87 oz. of gold, equivalent to 3·7 dwt. per ton.*
>
> "The first record of copper output appears to have been 10 tons raised by tributers, which returned 27 per cent. at Cockle Creek Smelting Works.†
>
> "In 1899 Inspector Milne reported that, after long suspension, this mine was opened under tribute by the Cobar Mining Syndicate, some rich bunches of carbonate and grey ore being obtained.‡
>
> "In the following year Inspector Godfrey reported that 'twenty men were employed under the tribute with satisfactory results on a small scale, no large bodies of copper ore being discovered, but occasiona rich small patches are found.'§
>
> "In August of the same year an output of 510 tons of ore, yielding 28 tons 15 cwt. of copper, is recorded."‖
>
> "In 1901 Inspector Schloesser reported that this mine had been steadily working some rich pockets of carbonates and sulphides.¶
>
> "In August, 1902, the tributers are reported to have extracted 2,353 tons of ore from Mount Pleasant, for a yield of 150 tons of copper, equivalent to 6·37 per cent.**
>
> "The Mount Pleasant and Young Australia are now held by the Cobar Copper Company, Limited.††
>
> "When once these lodes had revealed decided traces of copper, the efficiency of the cyanide plants (which had been erected to treat the stone of the upper levels) became seriously impaired. This difficulty, moreover, as Mr. Carne states, was 'enhanced by the extreme diffusion of the copper in the siliceous rocks forming the lode.'"‡‡

In the years 1900–01, more concentrated bodies of copper were found in the lower levels of the Mount Pleasant. In 1907 and 1908 Mr. Carne visited Cobar and made the following note‡‡:—

> "Position in October, 1907.—The new company was confining its operations to deepening the main shaft in the Mount Pleasant section from 340 to 530 feet, when it is proposed to crosscut the belt in the permanent sulphide zone. The previous developments at the 150 feet

* Ann. Rept. 1895, p. 29. † *Australian Mining Standard*, 22nd December, 1898. ‡ Ann. Rept., 1899, p. 100. § Ann. Rept., 1900, p. 102. ‖ *Australian Mining Standard*, 9th August, 1900. ¶ Ann. Rept., 1901, p. 89. ** *Australian Mining Standard*, 7th August, 1902. †† J. E. Carne, "Copper-mining Industry," p. 208. ‡‡ *Ibid.*, p. 200.

and 215 feet levels disclosed three main metalliferous bands in a width of 300 feet. The intermediate country, in addition to a general dissemination of metallic ores in infinitesimal proportions, contains thin streaks of more pronounced value, notably in the shaft at 340 feet.

"The east lode has a width of about 4 feet; it consists largely of manganiferous quartz, with patches of fair-grade copper ores. It lies 160 feet east of the main shaft, and has been stoped between the 215 and 150 feet levels, and proved in a winze below the latter to a reported depth of 70 feet. Between 150 feet and the surface it is unstoped. Sixty-eight feet west of the shaft, at both levels, a considerable width of auriferous ore has been stoped between the levels, and from the upper to the open surface quarry, in which gold was first obtained. Below the 215 feet level this band has not yet been followed.

Eighty feet west of the middle lode is the furthest western proving, known as the west copper lode, which has a width of about 8 feet. This band has been worked between the levels, and sunk on 40 feet below the 215 feet.

From the east and west lodes the copper ores were obtained for the Cobar smelters. The gold ore from the open cut and lower stopes is reported to have yielded about 6 dwt. per ton."

In 1908 Mr. Carne obtained the result of a series of twenty-eight assays of equally-spaced samples taken from the shaft in the Mount Pleasant, between the 215 and 400 feet levels. The average value of the gold thus estimated in the shaft was 1 dwt. 13 grs., and the average value of the copper was ·36 per cent.

A cross-cut was put in from the shaft to test the east lode (160 feet distant), and a chamber was made there and a drive run along the lode. The average assay of the platt was—gold, 2 dwt.; silver, 4 dwt. 1 gr.; and copper, 1·5 per cent. The average assays of the samples along the drive were—gold, 1 dwt. 19 grs., and copper, 2·58 per cent. A west cross-course was put in for 80 feet from the shaft at 400 feet, and its average assay, as stated by the Company, was—gold, 1 dwt. 15 grs.; silver, 3 dwt. 15 grs.; copper, 1·89 per cent.

Since that time the shaft has been carried down to a depth of 530 feet, and at a depth of 500 feet a drive was put in to the south for a distance of 504 feet. The workings are indicated on the accompanying Plates, illustrating the plans and longitudinal sections of both the Mount Pleasant and Young Australian Mines.

The Mount Pleasant Mine was closed down in the latter half of the year 1910. Specimens from the lowest level showed slates with splashes, veinlets, and little bunches of yellow copper sulphide of decided purity.

The Queen Bee Lode.

In this section, the line of lode comprising the Queen Bee proper, the Queen Bee South, and the Queen Bee North will be treated. These mines lie along a zone of decided crushing at the contact of altered argillaceous sandstones and slates. The sandstones form the eastern wall and are well cleaved, the bedding planes are obscured in many places; augen (eye) structures have been induced in the sandstones; frequent pebbles of quartzite occur in the mass, and these in places are sheared, in places elongated, and in other places apparently unaltered. The alteration appears to be confined to zones. The dips observable in the sandstones are easterly at angles varying from 45° to 55°, and the strike of the sandstones varies from 10° west of north to 5° east of north. [Fig. 20.]

The western wall of the lode consists of red and grey slates, which possess very high dips in a westerly to a southerly direction, and a strike at times approximating to east and west, and therefore opposed to that of the zone of crushing. The plane of movement dips slightly to the west, and thus is different to the general underlay to the east of the lodes in this district.

The zone of crushing is wide, and varies from 20 to 80 yards in width as shown at the surface. The strike is north 45° west, and is therefore opposed to that of the sediments, and the material crushed in places resembles a conglomerate, in others red and pink silky schists, and in others it resembles a breccia. Although slate forms the western wall of the zone of crushing, nevertheless traces of sandstones and a few quartzite pebbles are found 10 and 20 chains west of the zone of crush.

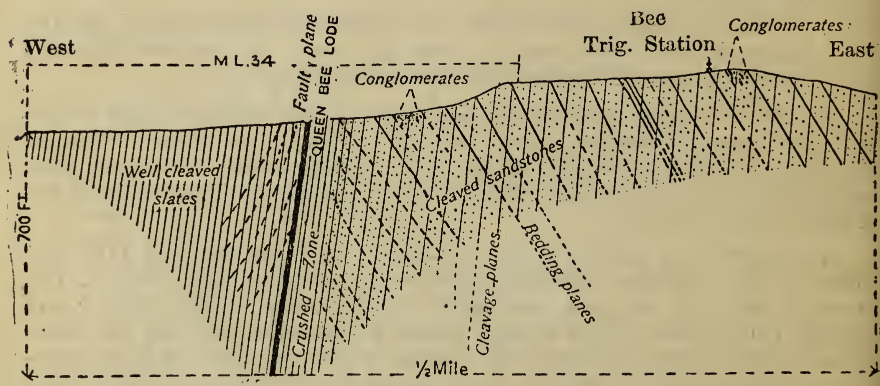

Fig. 20.

Sketch section across Queen Bee Lode in the neighbourhood of main shaft.

Queen Bee Copper Mining Company.—Leases: M.Ls. Portions 33 and 34, of 40 acres each, Parish Narri, and M.L. Portion 4 of 20 acres for lime stone, Parish Bee, County Robinson, and G.L. 36 and M.L. 14, Parish Narri.

History, Development. and Production.—The lode leased by the Queen Bee Company was originally prospected for gold about the same time that the Occidental (formerly The United) was first prospected. "The Queen Bee is paying dividends after having lain inactive for nearly thirty years."*

"The most successful is the Queen Bee Mine, some 12 miles south from Cobar, situated on the next hill to that of the Great Peak. Prospecting operations for gold some years ago were unsuccessful, though a considerable amount of trenching and a shaft 40 feet deep was sunk.

"The place was taken up again early in 1902, and being considered favourable for copper, Government aid was recommended, and granted, for sinking. At 85 feet, rich grey ores of copper were found, and the shaft has followed

* *Australian Mining Standard*, 3rd January, 1906, p. 12.

Photo. Great Cobar, Ltd.

Queen Bee Mine.

the ores down to 150 feet. At this level, drives have been started on the veins of rich ore that still show strongly. Good ore is also being mined from an underhand stope in the bottom of the stope.

"The ores are enclosed in walls of porphyry* and sandstone with blue slates, and ore, so far, of the enriched varieties, carbonates, oxides, and chalcocites; no yellow ores have been cut yet—the depth is not sufficient. Several shipments of rich ore up to 40 per cent. have been made. It is too early to say what this mine will develop into, but the results are highly encouraging and gratifying as an outcome of Government aid."†

Mr. Carne reported‡ :—

> "Rich grey sulphide struck in June, 1902, at 85 feet, and followed down to 150 feet. Drives started on rich ore at this level. First ore despatched in September. First copper produced at mine, June, 1904."

The Queen Bee Copper Mining Company (No-liability), of £25,000 capital, in 50,000 shares of 10s. each, began operations 15th December, 1903. The accompanying notes have been compiled partly from Mr. Carne's notes (p. 259) and partly from the half-yearly reports of the Company.

First year, ending 31st December, 1904.—Main shaft, 336 feet; greatest length of proving, 430 feet; widest part of stopes, 25 feet. Reverberatory furnace began in March; smelting in May. No. 2 furnace erected. No. 3 in December. Tanks of 2,000 cubic yards excavated. Rockbreakers, ore bins, workshops, picking tables, and other machinery installed.

Third and fourth half-years, ending 31st December, 1905.—Shaft down 425 feet; north drive extended to 497 feet from main shaft. Tank increased to about 7,000 cubic yards. Firebricks made at mine from the dense greyish felspathic sandstones forming the rough country east of the lode. No. 3 furnace started in March. No. 4 furnace completed in December.

Fifth and six half-years, ending 31st December, 1906.—Only two furnaces constantly employed during the first half of the year, others undergoing extensive repairs. No. 1 furnace being replaced by one of larger type. No. 5 furnace in course of erection. Winding engine, air-compressor, rock-drills, jigging plant (to treat 15 to 20 tons per day of accumulated fines), and other machinery installed and erected. Refinery built. New reduction furnace, to replace No. 1, completed. Main shaft, 485 feet deep. North drive at No. 3 level (370 feet) 422 feet, still in ore. South shaft, 435 feet south of main shaft, being sunk to prospect southern end of property.

Seventh and eighth half-years, ending 31st December, 1907.—South shaft 105 feet; main shaft, 563 feet; No. 1 level, northern drive, 483 feet; No. 2 level, northern drive, 543 feet; No. 3 level, northern drive, 438 feet; No. 4 level, northern drive, 516 feet; total sinking, driving, and cutting up to date 1,780, 2,726, and 522 feet respectively. Small blast furnace begun in March for experimental purposes. Had a run of forty days at 11½ tons a day; 100-ton blast furnace undergoing erection. Refinery started, and copper exported as refined ingots. No ore at this time was stoped south of the main shaft.

Ninth and tenth half-years, ending December, 1908.—Cross-cut 73 feet west from main shaft at 560 feet revealed sulphide lode of basic nature and 8 feet in width. Main shaft 602 feet. Small blast furnace found to answer better than original reverberatories.

* Altered sandstones (?).—E.C.A. † Inspector Schloesser's Report, Ann. Rept. 1902, p. 78.
‡ "Copper-mining Industry," p. 259.

Eleventh and twelfth half-years, ending December, 1909.—No. 2 small blast furnace was completed in August, and used instead of No. 1 furnace until November, when both were put into commission, Large Roots' blower and engine installed. Total amount of driving, cross-cutting, and sinking up to date, 3,618, 735, and 2,084 feet respectively. Application made for three months' suspension. Mine and smelting works closed down on 12th November.

Thirteenth and fourteenth half-years, ending December, 1910.—Mine closed during first half-year; reopened August, 1910. In April arrangements were made with the Great Cobar (Limited) to sample several large dumps of low-grade copper ore at grass, estimated to contain about 15,000 tons. The result of the sampling was not satisfactory to the shareholders, and the negotiations fell through.

Capital increased to £40,000 in 50,000 shares of 10s. each (ordinary) and 50,000 shares of 6s. each (Class A).

Fifteenth and sixteenth half-years, ending August, 1911.

A considerable amount of prospecting work was carried out both north and south of the main shaft. The main shaft was sunk 84 feet, giving a total depth of 697 feet. No. 6 level (at 670 feet) was opened up. A cross-cut west from the shaft was put in 133 feet, and at the 90-feet point it cut the lode; and drives on this were put in 80 feet north and 76 feet south, all in ore.

At the No. 5 level (570 feet) the main north drive was extended for 130 feet, giving a total length of 878 feet. This additional work was all in a zone of crushed material. The south drive was extended 67 feet, giving a total of 297 feet, all in ore. The cross-cuts off the south drive were put out 60 feet, and showed about 13 feet of low-grade ore. The winze in the south drive was sunk 44 feet, all in high-grade ore (sulphide). No. 3 level (370 feet), south drive, was extended 196 feet. Total length, 233 feet, partly in ore.

In driving the 570 feet level to the south, "the ore continued up to 172 feet, where it crossed to the east side, and has varied in width from 6 inches up to 3 feet, assaying from 3 per cent. to 13 per cent. copper. From samples taken every 5 feet, nice lode formation has existed full width of drive the whole way. Since the close of the half-year (February, 1911), cross-cuts east and west have been put out at the 200 feet point, the former being 26 feet and the latter 28 feet. After cutting 6 feet east, a strong body of ore was disclosed, 13 feet wide, of which 2 feet consists of high-grade ore, about 10 per cent. copper, and the balance 11 feet of lower grade."*

The directors point out that all the country south of the main shaft is virgin ground.

In the latter part of 1911 the mine was closed. In October of that year the mine was examined on behalf of the Mineral Separation Company, to ascertain whether the ore was suitable for purposes of oil separation. From small tests made, it would appear that the ore is suitable for this method of treatment.

In 1912 the mine was reopened and smelting recommenced.

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* Extract from Mine Manager's report.

Mr. Carne* also made the accompanying note on this mine in 1908 :—

"The reverberatory plant embraces four reducing and one refining furnaces of a capacity of about 70 tons per week each, one being occasionally worked to 100. The first run matte averages 40 to 42 per cent. copper.

"The small blast furnace, running on the best grade ore, with limestone and ironstone fluxes, averages about $11\frac{1}{2}$ tons per day, producing matte of 31 per cent., at a cost of £2 per ton of ore for smelting, according to the Company's eighth half-yearly report, the charge being :—

Coke	100 lb.
Raw sulphide	350 ,,
Slag	120 ,,
Limestone	150 ,,
Ironstone...	50 ,,
	770 lb.

"The coke and fluxes are slightly increased when slag runs thick.

"In view of the above results, with carefully-picked best grade (mostly pyritic) ore, the erection of a 100-ton blast furnace appears unwise. The best ore only can be treated by this method, at excessive cost for coke and fluxes, limestone and ironstone costing 10s. per ton for cartage. The Queen Bee ore on the average is too siliceous for ordinary blast furnace reduction."

The limestone flux is obtained on the Rookery-road, about 11 miles from the mine; its composition is shown in the following partial analysis :—

No. 07-7430—Calcium carbonate	99·03
Gangue	·53
Ferric-oxide and alumina	·14
Magnesium carbonate and undetermined	·31
	100·00

The average working costs of this mine for the five and a half years ending June, 1909, are here reproduced :—

	£	s.	d.	
Mining	0	18	0	per ton ore mined.
Dressing	0	3	0	,, ,, dressed.
Smelting (reverberatory) ...	1	15	0	,, ,, smelted.
,, (water jacket) ...	1	5	0	,, ,, ,,
Roasting	2	7	6	,, metal roasted.
Refining	1	7	6	,, blister copper (refined).

	£	s.	d.	
Mining	16	6	1	per ton of copper produced.
Smelting and dressing ...	28	18	4	
Development	5	19	5	
	£51	3	10	

For the six years ending December, 1909, the total ore raised was 48,440 tons, and the total amount sold or smelted was 38,738 tons. 6,426 feet of sinking, cross-cutting, and driving were carried out. The amount of copper turned out during that period was 2,838 tons. The amount spent on the

* J. E. Carne, "Copper-mining Industry," p. 260.

plant was £14,000, the total amount of wages £93,200, the total expenses £158,250, and the proceeds of the copper and ore £186,553. Attached is a set of returns from the Queen Bee Mine :—

Year.	Ore.			Yield Copper.	Value.	Total Value.
	Raised.	Treated.	Sold.			
					£ s. d.	£ s. d.
*1902	383	......	83	......	497 0 0	497 0 0
†1903	......	970	......	161	....	4,312 0 0
1904	1,469(?)	{ 1,150	......	136½	7,788 15 3 }	10,353 13 10
		......	319	......	2,564 18 7 }	
1905	7,854	5,388	......	499¾	....	31,534 15 7
1906	11,556	7,158	......	573	....	47,525 5 4
1907	10,235	6,422	......	493¼	....	37,087 2 10
1908	10,467	9,978	......	663½	....	35,378 8 10
‡1909	8,328	8,501	......	474	....	24,770 1 3
1910		Nil.		Nil.	....	....
1911		Nil.		Nil.	....	....
Totals	50,292	39,567	402	3,001	£10,850 13 10	191,458 7 8

* Returns from Mineral Resources, No. 69, p. 260. † Returns from Mineral Records.
‡ Mine closed down latter part of year 1909; reopened September, 1910.

Returns, unless otherwise stated, from the Queen Bee Copper Mining Company's Balance sheets.

The Plates illustrate the plan and longitudinal section of the mine There are six levels, Nos. 1, 2, 3, 4, 5, and 6, the depths below the surface of which are 150, 250, 370, 470, 570, and 670 feet, respectively. The lengths of the levels, commencing with No. 1, are, approximately, 585, 535, 535, 650, and 620 feet, respectively, the measurements being scaled off the longitudinal section of 30 feet to the inch prepared by the Company.

Three shafts were employed to develop the property, viz :—

A prospecting shaft, 150 feet in depth, sunk on the lode in which the first ore was struck at a depth of 90 feet. The distance of this shaft is 200 feet north-west of the main shaft.

A main shaft, 700 feet deep, vertical, and possessing three compartments. Size of shaft, 10 feet x 4 feet 6 inches in the clear.

South shaft, 150 feet deep.

Veins, Occurrence, and Character of Ore.

"The lode varies in thickness in the different levels from 1 foot to over 20 feet wide, intermixed with bands of country; in places proved solid for 5 to 10 feet wide. Best ore lens about 120 feet long; width, about 3 feet.

"At 450-feet level, an east lode struck in cross-cut about 15 feet from main lode. Width, 2 feet; ore, 4 to 5 per cent.

"A large body of slightly impregnated country, 30 feet wide, carrying about ½ per cent. of copper, occurs 70 feet west of main lode.

"The general lodestuff at the Queen Bee consists of slate, with copper and iron pyrites, and an appreciable quantity of zinc-blende and galena. It is broken and hand-picked over shaking tables before going to furnaces. It carries 1 to 2 oz. of silver per ton, but no gold."*

* J. E. Carne, "Copper-mining Industry," p. 260.

The general characters of the lode have already been described. Ferruginous gossan occurs in a few places, as at the site of the prospecting shaft. Generally, however, this outcrop is very siliceous. In the crushed zone containing the lode, the fragments resulting from the crushing appear in places as those of true breccias, while in others they appear as ellipsoids of impure silica.

At the surface the lode lies about 35 to 45 yards west from the main mass of the dense sandstone. At a depth of 150 feet a cross-cut was put in to the east, but the sandstones were not encountered. At the 570 feet level the main shaft is in crushed slate, and the sandstones still lie to the east. This is confirmatory of the field evidence, namely, that the Queen Bee lode lies in a plane of powerful movement, although the amount of throw cannot even be approximately stated at present, on account of the lack of outcrops and the great similarity of appearance among the sandstone beds themselves.

The underlay is about 1 in 12 in a westerly direction (S. 50° W.). In this respect it differs from the other lodes in the district, inasmuch as the Great Cobar is practically vertical, yet with a tendency to underlie east; while the C.S.A., Tinto, Cobar Gold, Chesney, Mount Pleasant, Occidental, and Peak lodes all underlie to the east.

Two veins appear to be worked, these being separated in places by a narrow "horse." In the northern stopes the veins approach each other, and finally coalesce. In other stopes two copper veins may be seen separated by a mass of iron pyrites. Farther south the "horse" is composed of altered slate. The "horse" commences near the No. 2 winze on No. 4 level, and is about 6 feet wide. It here contains about 3 per cent. copper. On No. 5 the "horse" dies out on the south side of No. 3 winze. On this level the eastern and western veins are separated by the "horse," which contains both iron and copper pyrites. On this level the lode and "horse" together are 22 feet in width. At the 150-feet level the eastern and western lodes were 25 feet apart, being separated by crushed and altered slate. Rich grey ore (chalcocite) was found on this level, having been worked from 90 feet below the surface. The western lode here was strongly brecciated. A typical section of the lode is illustrated in the accompanying Plates.

South of the main shaft a channel, from 2 to 3 feet in width, of splendid yellow copper sulphide was being worked in 1911. The ore consisted of an intimate mixture of impure whitish quartz and copper pyrites. An assay of the average stone from this spot, made at the Departmental Laboratory, gave the following return :—

[715–11.] Pyrites with quartz and slate gangue.

Gold	a trace.
Silver	2 oz. 14 dwt. 10 grs. per ton.
Copper	11·38 per cent.
Silica	12·57 ,,
Alumina*	5·03 ,,
Iron	31·92 ,,
Sulphur	31·95 ,,

* Includes any titanium dioxide, or phosphoric anhydride.

The minerals include silica, iron pyrites, arsenical pyrites, copper pyrites, grey sulphide (chalcocite), and blue and green carbonates. Silica is the most common mineral, and replacement of country by solutions containing silica appear to have progressed uninterruptedly during the formation of the ore deposit.

At a later stage came the introduction of iron and copper pyrites, the latter often in cubes. The sulphides appear to be commonly in the nature of replacements.

An interesting feature is the apparent absence of pyrrhotite, magnetite, and Ekmannite as a gangue, and the abundant presence of iron pyrites. The evidence points to the conclusion that there was sufficient sulphur in the ascending solutions to completely satisfy the demands of all the iron and copper present.

Water level occurred at a depth of about 250 feet. Above the first level (150 feet), rich carbonates and chalcocite were found. Between the second (250 feet) and first levels the mine manager stated that the bulk of the oxidised ores had been obtained. The level (250 feet) itself was apparently driven in yellow ore (chalcopyrite). Between the third (370 feet) and second levels "rich black ore" occurred (probably chalcocite). The yellow sulphides occur mainly below the water level; they were found to be rich just below the second level.

The ore worked at the lowest levels appears to be mainly primary in nature, and ore of a good quality may be expected to occur for considerable depths below the present workings, especially below the 570 feet level in the northern lens. The channels, however, are rather narrow. The main or northern shoot pitches steeply to the north. In mines such as these, where the lodes have been formed by the replacement of country along shear zones, it must be borne in mind that other lenses of ore may exist in parallel or subparallel zones of movement. Cross-cutting or diamond-drill boring should be constantly resorted to so as to ascertain:—

(1) Whether the main ore body has shifted east or west of the old channel.
(2) Whether other subparallel lenses of ore exist in the vicinity of the main lode.

No important cross-faulting of the lode has been detected in the mine. One or two minor planes of movement were observed, but none, however, that with ordinary care would give trouble in following the lode.

In February, 1909, Mr. J. O. Armstrong estimated the quantity of ore between the Nos. 3 and 4 levels at 2,300 tons dressed to 6 per cent., and at 10,000 tons between the Nos. 4 and 5 levels. He reported 8,000 tons of surface ore. The Queen Bee Company, however, estimated the ore lying on the surface at about 15,000 or 16,000 tons.

Queen Bee South.—M.L. 32, Parish Narri, County Robinson. This lode occurs in the continuation of the zone of crushing in which the Queen Bee itself occurs. Two shafts have been sunk on this line a few yards west of the sandstone mass. The accompanying extract is from Mr. Carne's "Copper Mining Industry," page 261:—

> "Inspector Polkinghorne reports that this site was taken up in 1902, after discovery of the adjoining Queen Bee Mine. Two shafts sunk—No. 1, 296 feet, No. 2, 175 feet—about 1,000 feet apart. Traces of copper only discovered."

In 1910 prospecting was continued in the northern shaft. By the end of the year it had been carried down to a depth of about 250 feet, and cross-cuts and drives had been put in, but without apparent success

The south shaft had fallen in during the visit of the Writer in 1910.

Queen Bee North.—M.L. 18, of 40 acres, Parish Narri. The workings consist of shafts and costeaning trenches to prospect the northern continuation of the zone of crushing traversing the Queen Bee leases. Copper stains were found, but nothing of importance was disclosed.

Great Cobar North.

This property adjoins the Great Cobar Mine, immediately to the north.

Leases.—The leases held by this Company include M.Ls. 11, 12, 13, 20, 21, 31, and 48.

Several siliceous gossan outcrops pass through the property. [See map attached]. The easternmost one is strong, and passes through the Great Cobar property about 30 feet east of the eastern elevated tram, along which the smelting charges are taken to furnaces. From this point the gossan outcrop crosses the Nyngan-road, and may be easily traced as a lode about 4 feet in width to the main railway line, a distance of 40 chains to the north. Another siliceous gossan outcrop crosses the Nyngan-road and passes between Nos. 3 and 4 shafts of the Great Cobar North. Another line occurs slightly to the west of this gossan, while the main lode of the Great Cobar appears to pass as an ill-defined but wide mass of siliceous fragments from 40 to 70 feet west of the No. 3 or main shaft. Beyond the main railway line to Nyngan the continuations of these outcrops cannot be definitely located. About 1 mile to the north of Cobar, however, a couple of strong quartz lodes have been traced, which appear to be continuous with the strike of the main Cobar lode. These underlie to the east, and have been prospected by the North Cobar Company, but without success.

The area within which the Great Cobar North is situated was taken up in 1871 by the original Cobar prospectors, but was not incorporated in the Great Cobar as the south blocks had been. The mine has been in the prospecting stage ever since. The idea in the minds of the various prospecting companies has been that a powerful line of lode, such as the Great Cobar main ore body is known to be, could not have disappeared within a short distance such as that between the northern workings of the Great Cobar and the northern boundary of their property, namely, about 300 or 400 feet. It is also thought that by sinking deeply enough along the boundary between the Great Cobar and the Great Cobar North the continuation of the Great Cobar lode will be found at a moderate depth. This inference is based upon the knowledge that the lenses of ore in the Great Cobar property have a definite northerly trend, as shown on the longitudinal sections approximately indicated on the map. This subject will be again referred to in a later paragraph.

History and Development.—The area under consideration is said to have been taken up three weeks later than the Great Cobar. The original company prospected the area by means of three shafts sunk on or along the gossans found close to the north boundary of the Great Cobar. No payable results were thus disclosed.

In 1901 Inspector R. Schloesser reported that:—

> "The North Cobar Mine has been sinking a shaft at the north end of the Great Cobar Company's mine to find the extension of their ore bodies. The shaft has been sunk 325 feet during the year, the intention being to cross-cut at 400 feet deep to cut the line of lode. It is unfortunate that the work of sinking this shaft was not added to one of those already existing further to the east; there would then have been a better and quicker prospect of success."*

In 1902 this shaft had been sunk to a depth of 500 feet, and a cross-cut had been commenced to the east to cut the line of the Great Cobar lodes.

The annual reports contain no reference to this property until 1905, when Mr. Inspector J. Polkinghorne reported that the North Cobar Mine had changed hands.

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* Ann. Rept., 1901, p. 89.

In 1908 Mr J. E. Carne* made the following report :—

"Later, for some unaccountable reason, a shaft was sunk 500 feet west of the strike to a depth of 520 feet, and a cross-cut started east from the 500-feet level.

"In 1906 the property was reported to have been purchased by the present Great Cobar North Copper-mining Company, Limited, on the strength of surface indications of a strong lode below, discovered (?) by the electric ore-finder.

"The west shaft was thereupon unwatered, andt he cross-cut extended 605 feet, or 100 feet east of No. 3 shaft on the Cobar strike, without encountering any more favourable indications than previously disclosed by the strike shaft.

"The latter was connected by a rise from the tunnel level and a winze sunk 40 feet below it (at date of inspection in October, 1907).

"For a width of 22 feet west, including the shaft, slate, with leaders of quartz, carries copper pyrites very sparingly. The winze was sunk in the best portion, where more copper sulphide was developed for a width of about 2 feet, a sample of which is reported to have assayed 4 per cent. Four inches of similar lodestuff was reported at the bottom of the winze, but water prevented close inspection of the lower part; a little galena is also associated with the copper sulphide. A small sample of picked clean ore from the lodestuff raised in sinking the winze assayed :—

No. 07-7,425—

Copper, 8·70 per cent.
Gold, a trace. } per ton.
Silver, 15 dwt. 6 grs. } per ton.

"An average sample of all the material raised from the 22-foot cross-cut in mineralised lodestuff and the 40-feet winze yielded :—

No. 07-7,424—

Copper, 0·25 per cent.
Gold, a trace. } per ton.
Silver, 4 dwt. 8 grs. } per ton.

"The strike of the orey belt was driven in 62 feet north, without, however, disclosing any metal values. To the south of the shaft, which is 24 feet south of the cross-cut from the west shaft, a drive has been extended 31 feet in a blank, no ore showing in face.

"It is proposed to deepen the shaft to 1,000 feet. The hope of this venture depends on the continuance of developments of a payable character in the lower northern extensions of the Great Cobar workings. If these continue to the boundary there are possibilities about or below 1,000 feet in the North Cobar Mine."

By the close of 1907 the eastern shaft had been carried down to a depth of 630 feet from the surface. The sulphide ore was reported to have improved with depth.

In 1908 the shaft had been carried down to 900 feet, and 322 feet of cross-cutting and 268 feet of driving had been completed. Most of the work appears to have been done at the 700-feet level.

In 1909 the main shaft was carried down to a depth of 1,130 feet; 800 feet of cross-cutting and 200 feet of driving were also carried out.

At the close of 1910 Inspector J. Polkinghorne reported that "197 feet of sinking, 467 feet of cross-cutting, and 1,087 feet of diamond-drilling" had been carried out.

* "Copper-mining Industry," 1908, pp. 246, 247.

"The driving and drilling were all done at the 1,300-feet level, being the deepest working level in the district. A large ore-body has been driven across, but it is very poor. The prospects obtained in the drilling have been such as to decide the company to sink the shaft another 200 feet. With reasonable despatch the lode should be proved at the 1,500-feet level during 1911."*

During 1911 the shaft had been carried down to a depth of 1,500 feet and a chamber excavated at that depth. The attached mine plan illustrates the method of prospecting adopted.

At present there are four shafts, Nos. 1, 2, 3, and 4, numbered from west to east. No 1 is 520, No. 2 about 300, No. 3 1,500, and No. 4 100 feet deep. No. 4 was sunk on the eastern outcrop of siliceous gossan, but nothing payable was disclosed by this shallow eastern prospecting.

The cross-cut at the 500-feet level is about 605 feet long, and the drive is about 50 feet long. The eastern cross-cut at a depth of 700 feet is 120 feet, and the western one 175 feet in length, while the north-and-south drive is 240 feet in length. No. 1 west cross-cut at 1,100 feet is about 50 feet long, the main west cross-cut is about 280 feet long, and the east cross-cut 250 feet long. The south drive is approximately 150 feet long.

At 1,300 feet depth the west cross-cut is about 175 feet, and the cross-cut west from the platt is about 50 feet in length, while the length of the south drive is about 160 feet.

A chamber has been excavated in the lode at the 1,500-feet level.

Veins, Occurrence, and Character of the Ore.—At the surface a strong siliceous gossan outcrop occurs at a distance of a few yards west of No. 3 shaft. At a depth of about 380 feet a number of quartz veins and veinlets appeared in the shaft, and these cross to the eastern side of the shaft (12 feet across) at a depth of 575 feet.

Thence to the No. 11 (1,100 feet) quartz stringers occurred all the way down the shaft. These all had an underlay to the east. At No. 11 level a series of quartz veins lie from 20 to 40 feet west of the shaft.

At No. 12 level (1,200 feet) the northern continuation of the Great Cobar lode appears to come in to the shaft from the west; hence all the way down to the 1,500 feet level the lode material occupies the whole of the shaft.

On the western side of the lode the slate appears to dip westerly at a high angle, while to the east of the lode the slate appears to be more contorted than that to the west, and to possess easterly dips in places.

At 1,450 feet a curious mineral association was found in the shaft. Here a wide mass of crushed slate and quartz veins, containing pyrrhotite, magnetite, and Ekmannite (iron silicate), came in suddenly, the iron minerals occurring as networks, lenses, and fibrous masses, the associated slate also being frequently of a green colour, and siliceous and cherty in nature; often also as large and tough shells, wrapped around lenticular kernels of quartz. The mineral is indistinguishable from that of the neighbouring Great Cobar lode. This is well illustrated in a large block of ore from the 1,500 feet level, and about 120 lb. in weight, now on exhibition in the Museum of the Department of Mines. It appears to be the northern continuation of the Great Cobar lode; nevertheless, whereas the galena and zinc-blende vein generally forms the western wall of the Great Cobar, it occurs at some distance to the west of the same lode in the Great Cobar North.

* Ann. Rept., 1910, p. 97.

Future of the Mine.—A careful study of the published working plans and sections of the Great Cobar Mine is most helpful in this connection. On the longitudinal section the southern lens is shown as having pitched about 250 feet north between the 4th and 10th levels. The southern portion of the middle lens appears to have advanced about 500 feet between the 4th and 11th levels. The northern extremity of the middle lens appears to have advanced about 350 feet between the 4th and 11th levels.

In the northern lens the heel, or southern extremity, appears to have advanced north to the extent of about 350 feet between the 3rd and 11th levels. The toe, or northern extremity, of the northern lens is shown on the working plans and sections as not possessing any northerly pitch. It must be understood, however, that the northern face of the northern lens on No. 8 level is still in good ore, while the northern faces of the northern lens along Nos. 10 and 11 levels are of considerable width, and the indications along these lower levels are such as to suggest that the northern lens in this part of the mine has made a considerable advance to the north of the upper northern workings.

An average of these measurements of northerly advance for the lenses of the Great Cobar Mine would suggest that the continuation of the northern lens may be expected in the Great Cobar North at a depth of from 1,700 to 2,000 feet, unless this northern lens decreases in length with increased depth.

Two suggestions may be put forward to account for the occurrence of the low-grade chalcopyrite-pyrrhotite-magnetite ore at a depth of 1,450 feet in the shaft of the Great Cobar North :—

(1) The Great Cobar North may be on the upper and poorer portion of an ore lens which is pitching into their property from the adjoining mine. In this case the lens would be the northern one of the Great Cobar, and the main mass of this lens might be expected at a depth of from 1,700 to 2,000 feet.

(2) The northern lens of the Great Cobar may be tending to the carrot form, as is suggested by a study of their working plans. In that case the ore body just found by the Great Cobar North might be considered as the upper portion of a new ore lens which is only making its appearance about 1,450 feet below the surface.

With regard to the first suggestion, namely, that the northern lens of the Great Cobar lode has pitched into the adjoining property, and may be expected to be found there at a depth of from 1,700 to 2,000 feet, it must be clearly understood that this is simply the evidence of the working plans and sections, and the knowledge that the lowest northerly faces of the northern lens in the Great Cobar are of considerable width, and that the southern portion of the same lens has advanced several hundreds of feet to the north in a vertical distance of about 800 feet.

With regard to the second suggestion, namely, that this may be the upper indication of a lens hitherto unknown, it may be stated that such an inference is in harmony with observations made in other regions containing lenses of copper in crushed country.*

Of these inferences it is, perhaps, more reasonable to suppose that the Great Cobar North are on the fringe of the northern continuation of the northernmost lens of the Great Cobar, and that the main mass of the lens may be expected at a depth varying from 1,700 to 2,000 feet. In any case, the ground is well deserving of prospecting to a depth of 2,000 feet, and of driving thence along the lode to the south.

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* It might be advisable also to prospect the eastern country.

C.S.A. GROUP.

This group of mines includes the C.S.A., the C.S.A. North, the C.S.A. South, the Tinto, and the Spotted Leopard. Prospecting operations have also been conducted along this line at the Water Tower, 1½ miles from Cobar in a west-north-westerly direction. The rocks are here considered to be of Silurian age, and they lie to the east of the fossiliferous Devonian quartzites of the Alley Belt. They consist of claystones, imperfect slates, well-jointed yellow flinty rocks, quartzites, and sandstones. The sandstones in places have been altered to quartzites by the introduction of silica along numerous tiny veins and "stringers" arranged in definite zones. In the C.S.A. Mine leases, the claystones may be observed to possess dips almost vertical. On the east of the main shaft the dips are contorted, but to the west of the shaft the rock dips are mostly to the west, at a high angle. In a few instances high eastern dips were observed. The rocks appeared to be here mainly of the nature of rocks not as strongly cleaved as typical slates.

It is evident that here earth movements have not been of such intense nature as in the more eastern areas. Strong faulting, however, is suggested as the cause of this line of silicification and ore deposition.

The C.S.A. Mine.

Leases.—M.Ls. 11, 12, 13, 21, 70, 72, and 112, Parish Kaloogleguy, County Robinson.

History and Development.—The C.S.A. lode was discovered about the year 1871. An old prospector named Tim O'Brien is said to have found a small vein of carbonate of copper on the outcrop where the underlay shaft now occurs. Hence a ton of copper ore was taken to Bourke by a Mr. John Collis. Three men—Messrs. Cornish, Gibb, and Conley—drove out with Captain Lean from Cobar to inspect the lode. A Mr. Nancarrow paid the money for the lease, in all £25, and the mine was started and named the C.S.A., from the respective nationalities of the three original leaseholders.

In 1882 the mine was reopened as the Scottish and Australian Mine.*

In 1886 the mine was again taken up by Captain Williams, after forfeiture by the previous party.

Encouraging prospects were obtained from the gossan in 1887. By the year 1888 two new shafts had been sunk 100 and 120 feet respectively, and drives had been put in from the old shaft, but with no good results. Want of water hampered this later group of prospectors, there being only 6 inches of rain in 1888.

In 1889 prospecting operations were again suspended.

In connection with these early attempts to prove the C.S.A. lode, a letter by Mr. G. H. Blakemore to the Department of Mines in 1905 may be of interest:—

> "Many years ago . . . . about 1,000 acres of land were leased in the neighbourhood of the C.S.A. Mine, as a glance at the old map will show. A great deal of excitement was caused in the Cobar district when it was discovered, and Mr. R. Hardie, of Sydney, informs me that a company, with a capital of £110,000, was floated to work the mine. No persistence was shown by the original prospectors, and they seem to have wasted their money in sinking a number of shafts and cutting costeans all over the hill, instead of starting in one shaft and sinking below the oxidised zone. The depth that oxidation has reached is notable."†

* J. E. Carne, "Copper-mining Industry," 1899, p. 154.

† Ann. Rept., 1905, p. 42.

In all these attempts the prospectors did not appear to have perceived the necessity of getting well below water level, so as to ascertain the value of the primary sulphide body.

"From the years 1895 to 1899 the mine was held by H. Cornish and party, who received Government aid to continue the shaft a further depth of 100 feet; but after completing this work, and a certain amount of driving, operations were suspended."*

At a later date, Inspector D. Milne reported (P.B. 594–99) that several shafts had been sunk on different veins of copper ore, and in the large gossan lode a shaft had been sunk 250 feet. The lode at this level was very wide, and carried a little gold all through, with occasional veins of lead carbonates in gossan.† Aid was granted to sink to 350 feet, and to cross-cut 50 feet at that level. After carrying the shaft down 332 feet operations were abandoned, no payable ore being discovered at that depth in the still persistent porous gossan.

In 1904 a fresh attempt was made to prospect this property. Previous work had been productive of a main shaft 350 feet deep, with drives and cross-cuts from the bottom of the shaft.

In 1905‡ the C.S.A. Development Syndicate commenced operations in March, the shaft then being 332 feet deep. "Prospecting aid was granted to sink the shaft a further 150 feet, and after sinking 125 feet water was met with. A cross-cut was then started east, and after going a few feet a body of rich carbonate of lead was met with. The cross-cut has been driven 168 feet, and the face was still in lode matter. From the developments at the level, which consist of a cross-cut east 168 feet and west 50 feet, drive north 100 feet, and south 50 feet—all in lode matter—it appears that this is destined to become a large productive mine. A winding and air-compressing plant have been installed, and preparations made to instal a diamond-drilling plant to prove the ore body at a greater depth."§

Mr. Inspector Polkinghorne also reported as follows in 1906 :—

> "At the C.S.A. Mine there were fifty hands employed during the year. The ore produced and sold amounted to 1,923 tons, and realised £17,238. A new shaft was started and sunk 250 feet, and a large amount of driving done from the old shaft. A new winding engine was erected at the new main shaft. A system of square-set timbering has been inaugurated in this mine. . . . The new main shaft is being pushed on to connect with the workings from the old shaft."‖

In 1907, 1,367 tons of ore were raised, of which 1,024 tons were sold for a return of 355 tons of lead, 1,223 oz. silver, and 87 oz. of gold, valued at £6,500. "Machinery to the value of £3,100 was added to the plant. The main shaft was sunk 472 feet, and is now 595 feet. A platt was cut at the 454 feet level, and connected with the drive from the old shaft; another platt was cut at the 560 feet level."¶

During the year 1908 a considerable amount of development work was carried out, and large bodies of low grade mixed sulphides were proved.**

Up to the 10th March the Company had expended £59,867 without any return to the shareholders.

* Ann. Rept., 1906, p. 42. † J. E. Carne, "Copper-mining Industry," p. 200. ‡ Ann. Rept., p. 80. § Inspector Polkinghorne's report. ‖ Ann. Rept., p. 95. ¶ Inspector J. Polkinghorne, Ann. Rept., 1907, p. 91. ** Ann. Rept., 1908, p. 5.

In the year 1909, the C.S.A. Mine was closed down, but was reopened in August, 1910. After driving a few feet from No. 1 east cross-cut from the old shaft, a nice body of copper ore was met with. This was in No. 1 level in the old shaft, or 452 feet below the surface. This is the best strike of copper ore the mine has produced.*

In the years 1910 and 1911, a search was instituted for copper veins in the country lying immediately east of those already known to exist in the mine. This prospecting work consisted of extending drives and cross-cuts from the 450 and 560 feet levels. As a result of such prospecting work the existence of a body of siliceous copper ore was disclosed. At the 560 feet level this ore became rather more siliceous. Mr. C. R. Mackenzie, manager of the C.S.A., has informed me that this eastern body was driven along, the values at first being 5 to 6 per cent. copper. After driving "a distance of 100 feet in this ore, then came a blank for 20 feet, then came a nice body of basic ore, very much like the Tinto ore; only 10 feet have been driven since cutting this."

At a still later date the Writer had an opportunity of visiting the C.S.A. Mine. A body of basic ore very similar to the pyrrhotite ore of the Tinto Mine was being prospected and it is the intention of the Company to drive on it to the Tinto body to the south. The new body of stone carries good copper values but its width has not been proved. If this body should persist to the Tinto Shaft it will give a new life to the C.S.A. A parcel of lead ore (600 tons) stated to contain 50 per cent. lead is about to be sent to Cockle Creek.

Development.—The plans illustrate the amount of work carried out in the C.S.A. The main shaft is vertical and 660 feet in depth, 12 x 5 feet in the clear. Another shaft, about 250 feet south-east of the main hauling way, is also vertical, and 460 feet in depth. The method of prospecting adopted in testing these irregularly shaped bodies is shown on the plan. Four main levels exist, exclusive of the old prospecting workings, as shown on the accompanying plan. The depths of these levels below the surface are 225, 454, 560, and 660 feet respectively.

The approximate lengths of some of the more important drives and cross-cuts are here supplied :—

	Feet.
No. 2 Level (457 feet)—	
Length of western cross-cut from main shaft	844
,, main south drive	493
,, main north drive	125
,, No. 1 east cross-cut	170
,, No. 2 east cross-cut	215
,, No. 3 east cross-cut	155
,, No. 4 east cross-cut	122
,, No. 1 west cross-cut	110
,, cross-cut east of main shaft	275
,, cross-cut west of old shaft	200
,, lead stope	120
Width of lead stope	40
No. 3 Level (560 feet)—	
Length of western cross-cut from main shaft	348
,, south-eastern cross-cut from main shaft ...	215
,, main northern drive	165
No. 4 Level (660 feet)—	
Length of western cross-cut from main shaft	275
Length of eastern cross-cut from main shaft	230

* Inspector J. Polkinghorne, Ann. Rept., 1910, p. 97.

Veins, Occurrence, and Character of Ore.—The C.S.A. outcrops consist of ferruginous and siliceous gossans. Some are disposed in definite lines, but the main exposure is a large boat-shaped mass of brick-red gossan. Beneath the surface, however, this great gossan mass is observed to pass into several fairly definite lines of iron pyrites containing copper, lead, and zinc, separated by wide belts of unproductive claystones and slates. The whole appearance of these ore masses is strongly suggestive of the replacement of claystone and slate country by iron, copper, lead, and zinc sulphides. The main sulphide replacement underlying the great gossan outcrop is shown on the attached plan as the "lead stope." The causes leading to the replacement under consideration are not yet understood, although the arrangement of the rock dips in the vicinity of the ore body is such as to suggest the formation of the ore along a fault plane with local intensity of crushing in the neighbourhood of the "lead stope." By this means the ascending solutions obtained readier access to the whole of a wide zone of rock, and thus chemical action was facilitated.

The minerals found are copper pyrites, chalcocite, azurite, malachite, carbonate of lead, chloride of silver, galena, zinc-blende, quartz and flint. Ekmannite and magnetite have not yet been recorded, although it is probable that in driving southwards towards the Tinto Mine, such minerals most probably will occur.

In the upper 400 feet a dark gossan with traces of carbonates of copper and lead were found. Near water level a large boat-shaped mass of lead carbonate was discovered, while at a very short distance below the surface of the zone of permanent saturation sulphides of iron, copper, lead, and zinc took the place of the lead carbonates.

In this connection the report of Mr. J. E. Carne is very significent.* After pointing out that Mr. Inspector J. Polkinghorne recommended further aid [P.B. 2,299–05], which was granted, to deepen the shaft to a depth of 482 feet, and to cross-cut 75 feet east and 50 feet west, he writes :—

> "Water level was reached at 457 feet, and a cross-cut started a few feet above it, in which rich carbonate of lead was struck—*the redeposited concentrated result of 450 feet of leaching. Below the water level, the change to lean sulphides of iron, lead, and copper was sudden.* [The *italics* are mine.—E.C.A.]
>
> "The company, formed as a result of the rich lead strike, is now sinking the new main shaft well below the water level for the purpose of testing the sulphide zone, the success of the mine depending upon the existence of sufficient copper sulphide to form matte in blast treatment. Until this is proved its future is problematical. In the north end of the property stains of copper carbonates are visible in the old shaft tips, but levels driven at 450 feet to these points have not been encouraging. In the bores to a depth of 150 feet below the 450 feet level fair copper values prevailed for a few feet, but soon diminished to unworkable proportions. In the drive from the main shaft to the lode at 450 feet, thin plates of native copper were encountered in a few feet of country."

The average thickness of the lead carbonate body found near water level does not appear to have exceeded 30 or 40 feet. (See plans.) And this must, as Mr. Carne states, represent the reconcentrated portion of the upper 400 feet of the lode at least. Lean sulphides of copper and lead succeeded to these almost as soon as water level was passed.

* "Copper," 1908, p. 201.

The existence of lean cupriferous iron pyrites beneath the lead carbonates and galena suggests the existence here of ore bodies younger than the pyrrhotitic copper bodies of the field. These have not yet* been proved in the C.S.A. leases. The occurrence, however, of cupriferous pyrrhotite in the Tinto, possessing an appearance almost indistinguishable from that of the Great Cobar Mine, and possessing a strike of about north 20° west suggests that this body will persist into the C.S.A. blocks.

In the year 1910 a search was made to the east of the main workings in the C.S.A. to ascertain the possible existence of copper bodies which outcropped as gossans eastwards of the main gossan exposures at the surface. Mr. Mackenzie, as manager of the mine, exploited the country by cross-cutting from the drive to the south of cross-cut No. 1 east on the 450-feet level, and almost immediately came upon a body of yellow copper ore, 8 to 10 feet wide.

An assay of this ore at the Departmental Laboratory gave the following result:—

575.—C.S.A. Mine.

Copper	16·60 per cent.
Iron...	17·64 ,,
Sulphur	23·82 ,,
Silica	26·67 ,,
Gold...	a trace.
Silver	5 oz. 8 dwt. 21 grs. per ton.

The assay of a representative parcel of this eastern ore, sold to the Great Cobar, Limited, is also attached :—

Copper	5·60 per cent.
Iron...	16·07 ,,
Insoluble	48·00 ,,
Alumina	4·45 ,,
Sulphur	17·97 ,,

In describing the work done along this eastern body at the 457-feet level, Mr. C. R. Mackenzie wrote, under date December, 1911 :—

> "We drove along this body in from 5 to 6 per cent. ore for a distance of 100 feet, then came into a blank for 20 feet, then into a nice body of basic ore, very much like the Tinto ore. It is highly probable that this will continue to the Tinto workings."

The ore is copper pyrites in a schistose matrix, porous and coated in places with what appears to be black sulphide of copper. This body of ore has the appearance of secondary origin, and it is impossible at present to state definitely what are the values of the primary sulphide body from which it has been derived. At the 560-feet level the vein has been cut and silica is more pronounced than in the overlying level, while the copper values are not so good as along the upper level. The width of this eastern lode is unknown.

To the west it appears to be cut through by a zone of crushing in which galena, zinc-blende, and iron pyrites occur.

With respect to the character of the two larger veins of ore, it may be stated that both are iron pyritic bodies of considerable width, with varying admixtures of lead, zinc, and copper. The copper contents are low, and until the Company find other sources of copper than the two veins under consideration, the C.S.A. lodes, as at present known, must be considered rather in the nature of basic fluxes than in that of copper ores. The larger or eastern

* Pyrrhotite has been found in considerable quantity at a later date.

body has been worked for a width of 40 feet, and it contains a rather high admixture of lead and zinc. In this the sulphur percentage is about 35 and the iron excess is about 18 per cent. In another portion of this, outside of this wide zone (41 feet), lies another belt of ore 41 feet in width also, and in this the lead and zinc content is almost negligible, so far as assays have been taken; nevertheless the silica excess is about 1 per cent., with the sulphur content 29 per cent.

In the large western ore body, a body of stone about 18 feet wide has been assayed on both Nos. 2 (457 feet) and 3 (560 feet) levels. In this body the result of nineteen samples show that the lead and zinc content is negligible, while the sulphur content is 39 per cent. and the iron excess 33 per cent.

Attached is a table of approximate values of the ore (exclusive of copper contents) from these basic bodies, as supplied by the C.S.A. Company :—

Average Assays.—(Supplied by C.S.A. Company.)

	Basic Ore.	Width.	S.	Fe.	SiO_2.	Zn.	Pb.	Al_2O_3
Eastern Ore Body— No. 3 level (560 feet) S.E. cross-cut ..	182 ft. 6 in. to 224 ft. ..	41 ft. 6 in.—8 samples of 5 ft. each.	35·2	26·3	8·3	16·6	7·6	..
" " ..	244 ft. to 285 ft. ..	41 ft.—9 samples	28·7	27·5	28·6	4·9	1·5	..
South drive off S.E. cross-cut.	1 ft. to 132 ft. in basic ore.	30 samples	31·3	24·9	11·6	12·2	6·3	6·07
No. 4 level (660 feet) E. cross-cut just into basic ore.	....	1 sample, 4 ft. wide ..	39·7	31·6	14·6	3·0	..	8·80
Western Ore Body— No. 2 and No. 3 levels.	Basic ore, 18 ft. ..	19 samples	39·1	38·5	5·3	3·0	0·65	..

Attached are assays of parcels of ore totalling several hundreds of tons supplied to the Great Cobar, Limited, in 1911. The ore under consideration appears to have been obtained from the western vein. The copper values are not reproduced.

Assays by Great Cobar, Limited.

	A.	B.
Iron...	35·74	35·39
Insoluble	7·55	7·70
Alumina	2·84	1·74
Sulphur	35·44	37·30

In conclusion it can only be said that the C.S.A. Mine, so far as it has been developed, does not possess sufficient copper values to enable it to be worked alone as a copper ore. It is, however, a very fair copper flux. From all the known laws of copper deposition, and from a knowledge of the geological structures in the locality, one cannot expect the copper or lead values of the C.S.A. lodes to improve with increasing depth, and the only apparent hope of finding copper sufficient in amount to enable the C.S.A. to be worked by itself as a copper-mine, is to develop the adjoining Tinto Mine, to connect the workings of the two mines by development work carried out along the ore channels, and to further exploit both the eastern and western country of the C.S.A.

Since writing the above, the C.S.A. have carried out a considerable amount of the development here outlined, and the prospects are very encouraging. The mine may be expected to be worked as a copper-mine at any time.

In the Appendix the suitability of this basic ore as a flux is considered.

Attached is a copy of the production of the mine up till December, 1911 :—

C.S.A. Mine.

Returns from Mine Records, *per* Chief Inspector of Mines.

Year.	Tons treated.	Yield.			Value.	Copper.
		Silver.	Lead.	Gold.		
1904		Developmental work.				
		oz.	tons.	oz.	£	
1905	300	600	......	......	75	
	......	......	150	......	2,400	
	......	......	......	30	120	
1906	3,800	3,800	......	......	475	
	......	......	912	......	16,516	
	......	......	......	*235	950	
1907	1,200	1,200	......	......	150	
	......	......	288	......	3,750	
	......	......	......	60	240	
1908		No ore raised.				
1909		No work done.				
1910		Work resumed in August of this year.				
1911	491	......	......	......	1,259	·22½
Totals......	5,791	5,600	1,350	325	25,935	22½

The Tinto.

Portion M.L. 17, Parish Kalooglεguy, County Robinson.

History and Development.—The old name given to the Tinto Mine was Gardiner's Blocks.

In 1905 a shaft was put down in this lease for a depth of 200 feet on a ferruginous gossan, lying about 15 chains south of the main C.S.A. shaft.

In 1906 the shaft was sunk a further depth of 218 feet, making a total of 418 feet from the surface along the underlay. A cross-cut, 52 feet west at the 418-feet level was reported to have intersected a rich body of carbonate ore. The ore raised from this depth had an average value of 1½ oz. silver per ton, and 15 per cent. lead.*

The underlay of the lode being to the east, a vertical shaft was commenced in 1907 east of the lode, and sunk to a depth of 80 feet, the size of the shaft being 12 feet x 4 feet in the clear.

In the year 1908 the main vertical shaft had been carried down to a depth of 450 feet. A cross-cut was driven thence to the west, and at a distance of 26 feet a lode was cut carrying rich oxides and black sulphides of copper.†

In 1909 the name Gardiner's Blocks appears to have been changed to that of Cobar Tinto, and a considerable body of copper oxides and sulphides were won near water level.

In 1910 the main shaft was deepened a further distance of 85 feet, making a total depth of 530 feet. At this depth the lode was intersected, a considerable body of primary sulphides being exposed. A platt was excavated, and driving commenced north and south at this level. In this development work a mass of flint (or slate partly replaced by silica) with poor copper values impeded progress, and the mine was closed down. It is to be hoped that this mine will be worked again, and a vigorous prospecting

* Ann. Rept., 1906, p. 42. † *Ibid.*, 1908, p. 45.

campaign be carried out between the Tinto and C.S.A. Shafts. The ore samples examined by the Writer in 1910 from this lower level (530 feet) were of primary nature, being composed of pyrrhotite, magnetite (?), chalcopyrite, and flinty slate (see Plate 24), and they carried good copper values.

Attached is a table showing the yield of the mine up to date.

COBAR TINTO MINE (formerly known as Gardiner's Blocks).

Year.	Tons raised.	Tons treated.	Tons sold.	Yield.				Value.
				Gold.	Silver.	Lead.	Copper.	
	ore.	lead.	carbonate.		oz.	tons.	tons.	£
1906	300	300*	......	...	450	45	......	900*
1907	80	47	47	...	...	...	5	350†
1908	......	......	......	...	...	...	......	......
1909	2,385	......	1,485	...	...	...	113	6,831‡
1910	2,364	......	2,364	113	132	...	123	7,586§
1911	97	......	97	...	...	...	3½	190
Totals	5,129	347	3,994	113	582	45	244½	£15,667

Veins, Occurrence, and Character of the Ore.—The strike of the gossan outcrop is about north 20° west. The dip is steep and easterly. Apparently the lode is continued into the C.S.A. Block (portion M.L. 4), and appears to run east of the main C.S.A. lead lode. The gossan outcrop was of rather more siliceous nature than the main C.S.A. example. The C.S.A. outcrop occurs on the summit of the gentle rise known as the Elouera Trigonometrical Station, while the Tinto outcrop runs along the southern slope of the hill. Water level occurred at a depth of about 430 feet, and the reconcentrated copper, lead, gold, and silver ores from the upper lean zone were found at and just above the zone of permanent saturation. The plate illustrating the plan and longitudinal section of the Tinto Mine, shows the depth, length, and width of this limited mass of enriched ore. It is from 170 to 180 feet in length, from 20 to 30 feet in width, and from 30 to 35 feet in height. Rich oxides and sulphides of copper composed the main portion of the deposit.

The upper surface of the mass of secondary ores under consideration was markedly irregular, as may be seen upon reference to the accompanying longitudinal section. The line of separation between rich secondary ore and unproductive gossan appears to have been remarkably pronounced.

In the cross-cut west from the shaft to the lode, at a depth of 450 feet, the chalcopyrite and pyrrhotite lie to the east of the lead, zinc, and iron pyrites body. The two bodies appear to be contiguous or continuous in places. The lead and zinc body proper appears to be younger than the main copper deposit.

The minerals found in the mine are quartz, calcite, chert, iron pyrites, galena, zinc-blende, cerusite, azurite, malachite, chalcocite ("grey ore"), chalcopyrite, pyrrhotite, magnetite (?), gold, and silver. The body of ore cut in the main shaft, at a depth of 530 feet, is a massive and basic variety

* Ann. Rept., 1906, p. 42, Mine Records. † Ann. Rept., 1907, p. 90. ‡ Ann. Rept., 1909, p. 107; net return, £3,328; Ann. Rept., 1909, p. 46. § Ann. Rept., 1910, pp. 46, 96; estimated yield and value.

composed of chalcopyrite and pyrrhotite, with fragments of siliceous slate and of chert. Plate 24 illustrates the appearance of this ore from a more acidic portion of the deposit.

An analysis of this ore, made in the Departmental Laboratory, gave the following results :—

[716–11.] Dense pyrites (chalcopyrite and pyrrhotite).

Copper	9·72 per cent.
Iron	44·80 ,,
Sulphur	32·52 ,,
Silica	4·45 ,,
Gold	a trace.
Silver	2 oz. 4 dwt. 15 grs. per ton.

Forty-seven tons of ore sent to the Great Cobar, Limited, from the bottom of the Tinto shaft are said to have assayed 4·70 per cent. copper and 37 per cent. iron.

According to the returns furnished to the Department of Mines, two parcels of copper ore were sold from this mine in 1909 and 1910 respectively, that of 1909 amounting to 1,485 tons for a yield of 113 tons of copper, or 7·6 per cent. of copper, while the parcel for 1910 amounted to 2,364 tons for a yield of 123 tons of copper, or 5·2 per cent. of copper.

The ore found to the west of the chalcopyrite and pyrrhotite contained a considerable percentage of galena, zinc-blende, and iron pyrites.

This part of the ore body lacks the compact and resistant appearance of the pyrrhotite body ; it is " heavy " ground, and appears to be of later origin than the basic mass to the east.

Other Mines along the C.S.A. Line.—The mines enumerated here, although not so important as some to be described hereafter—for example, the Gladstone—are included in this chapter, so as to complete the description of a mining unit.

As a result of the wonderfully rich bodies of secondary ore found during the year 1905 in the C.S.A., a great number of leases, aggregating 5,198 acres in area, were applied for during the year in this locality.*

The more important of these prospecting claims were Block No. 19, M.L. 10, No. 18, The C.S.A. Central, The C.S.A. South, M.L. 49, and The Spotted Leopard, all in parish Kaloogleguy, county Robinson.

The prospecting work carried out on these leases consisted of shaft sinking, with a moderate amount of cross-cutting and driving. The shafts were all sunk either on patches of ferruginous or of siliceous gossan. In certain instances a belt of quartzite, traversed by quartz stringers and veinlets, was taken as a guide, and in still others guides were found in patches of red and manganese-stained claystones, such as those occurring both on the Water Tower Hill, the Spotted Leopard, and the C.S.A. Hill.

A deep vertical shaft was sunk on the iron-stained claystones in M.L. 10 (part of the C.S.A. leases), but nothing of value was found.

On the same line as the C.S.A. outcrop a vertical shaft was put down by the C.S.A. North to a depth of 300 (?) feet, without result.

In Block No. 19, lying to the north-west of the C.S.A. main shaft, the C.S.A. North put down a vertical shaft 400 feet in depth with cross-cuts and drives thence totalling about 150 feet, but without obtaining results other than traces of copper ore.

* Ann. Rept. 1905, p. 42.

Another shaft was put down at the boundary of M.Ls. 4 and 21 to test the promising-looking gossans traversing M.L. 11. Nothing of value resulted.

Three or four deep shafts were sunk by the C.S.A. Central about 60 chains to the south-south-east of the main C.S.A. shafts, without result.

Two deep shafts were also sunk a little to the east of the C.S.A. Central shafts, one in M.L. 22 (203 feet deep) and one in M.L. 64. These appear to have been sunk by the C.S.A. South. No values were found.

Another shaft was sunk on the same line, about 6 miles to the south-south-east of the C.S.A. In this shaft nothing of value nor of promise was found.

The Spotted Leopard, M.L. 2, 40 acres..—The outcrop is a mass of red iron-stained and manganiferous claystones and mudstones, similar in appearance to the country outcrop of the C.S.A. Mine about 2 miles to the north. The strike of these sediments is approximately north-north-west, and the dip is from 70° to 80° to the west-south-west.

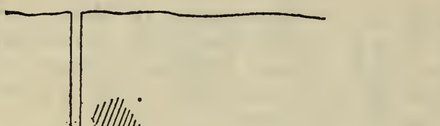

Fig. 21.

Sketch Section across Spotted Leopard Mine Workings.

The lode has been prospected by a vertical shaft 200 feet deep, and by cross-cutting at depths respectively of 100 and 200 feet. The claystones are well bedded and cleavage is characteristically absent. Faulting on a small scale is fairly common, and both faults and lode dip at moderate angles to the east.

A cross-cut was put in at the 100-feet level for a distance of 66 feet to the east. Ten feet in from the shaft a kind of lode material was intersected, and this was found to be 40 feet in width.

At a depth of 200 feet another cross-cut was put in 150 feet to the east, and at a distance of from 70 to 100 feet in the cross-cut a mass of claystones with quartz veinlets, vughs containing iron and manganese, and silicified country was passed through. This imperfectly replaced country at 100 feet in the cross-cut is said to assay 6 dwt. of gold per ton. The prospects are not encouraging for copper so far as the work has been carried out.

The minerals found were carbonate of lead, galena, manganese, iron oxide, and quartz. Water-level has not yet been reached.

The Cobar Gladstone Mining Company.

Leases.—Mineral and Private Lands Leases from Crown. Total area, 29 ac. 10 per. Private Lands Lease Nos. 3, 130 to 139, inclusive. M.L. Nos. 805, 806, and 851, Parish Cobar, County Robinson.

Situation.—About 2 miles S.S.E. of Post Office, Cobar.

History and Development.—In the beginning of the year 1907 prospecting operations were continued at the Gladstone on a ferruginous gossan. A shaft 30 feet in depth had been sunk many years previously, but without payable results. In the new shaft copper indications were met with at a depth of 80 feet, and by September 1908 the shaft had been sunk 180 feet, and a cross-cut driven east. Two veins of copper were proved by this cross-cut, and 8¾ tons were taken thence and sold to the Great Cobar, Limited, for a return of 2 tons of copper. This ore was obtained while "extending the drive 73 feet from a 24-feet cross-cut from the prospecting shaft (186 feet deep). A new shaft was started, and at the end of the year was down 90 feet. . . . The new shaft is . . . 11 feet by 4 feet."*

The same officer made two reports in 1909 and 1910, extracts from which are here reproduced: "In 1909, the new prospecting shaft was sunk to a depth of 219 feet, and a drive extended south for 300 feet, proving the lode the whole distance. High grade ore was passed through. At a depth of about 200 feet in the shaft, water was encountered, making about 30,000 gallons a day."†

In 1910, the shaft had been sunk to a depth of 260 feet. "A level is being extended south at the bottom of the shaft . . . It is not expected that payable ore will be met with in less than 100 feet of driving." Water was very heavy, coming in at the rate of about 74,000 gallons a day.‡

In 1911, the shaft was not sunk deeper, but a long level was put in from the bottom of the shaft. "The south drive from main shaft at the 260 feet level has been extended 314 feet (face still shows payable ore), cross-cuts put out from same totalling 31 feet, and drive connected with three winzes from No. 1 level, totalling 150 feet of sinking."

"The ore produced and sold, which totals 711 tons net weight, and returned £2,249 net at the smelters, has all come from the above development work, excepting some very high-grade ore which was broken from a small stope for despatch to the "Waratah" works for treatment, as at that time arrangements had not been completed to dispose of our ore locally.

"The drives and winzes have practically all been in ore to the full extent, and cross-cuts have so far not touched any walls.

"*Stoping.*—At 135 feet south from main shaft, opposite No. 1 winze, on east side of drive, have opened a small stope about 20 feet long, 10 feet high, and 5 feet wide, from which some high-grade black ore, worth 22 per cent. copper, has been broken. At this locality the ore body is 20 feet wide. At a point about 255 feet south from main shaft, in the vicinity of No. 2 winze, have opened another small stope 20 feet long, 20 feet high, and 5 feet wide, on good average ore worth 7 per cent. copper."§

Veins and Ore Occurrence.—The Gladstone copper lode occurs in a crushed slate zone. The outcrop is of siliceous gossan and a little to the south of the old prospecting shaft it may be observed to split into two, one branch passing under the English Church and the other under the Roman Catholic Church. Neither of these branch veins has been prospected. Northwards of the main shaft also the vein has either split into two, or it exists as two parallel fissures separated by a fairly wide zone of crushed slate. This area has not been prospected. Still farther to the north the strike of the Gladstone crosses the main road to Cobar near the overhead tramway of the Cobar Gold-mine. Here the slate is traversed by a great number of lenticular quartz veins arranged along a narrow zone. The Gladstone vein has a powerful slate structure for a hanging wall and a much weaker slate structure for the foot-wall. At each place where observations of such phenomena have been

* Inspector Polkinghorne, Ann. Rept., 1908, p. 95. † Ann. Rept., 1909, p. 107.
‡ Ann. Rept., 1910, p. 96. § Extracts from Directors' Report for half-year ending June, 1911.

possible, the dips of the hanging wall (eastern) are high and easterly. This is peculiar, because the prevailing dips of the slates in the neighbourhood of Cobar itself are high and westerly.

The lode appears to be intimately related to the Great Cobar lode, which lies about 1½ miles to the north-north-west, nevertheless its strike is not continuous with that of the Great Cobar, but is only parallel to it at a distance of 200 or 300 yards to the east. Like the Great Cobar also, it is almost vertical and occurs, approximately, at the junction of two classes of slate. The mineral association, however, is quite different.

The minerals found up to the present are quartz, azurite, malachite, cuprite (red oxide of copper), native copper, chalcocite ("grey ore"), chalcopyrite (yellow ore), limonite, and hæmatite. All these are secondary minerals as far as found. Even the chalcopyrite is bright yellow, and occurs in streaks and bunches, coated with thick sooty sulphide (chalcocite), and set in a soft earthy matrix. The hæmatite also is decidedly of secondary origin, being of a soft massive variety intimately associated in the upper portions of the vein with earthy red copper oxide, chalcocite, and malachite. This mineral does not occur in the primary zone at the Great Cobar, but gives place to pyrrhotite and magnetite at slight distances below water-level. Pyrrhotite, magnetite, and chalcoypyrite may be expected at a moderate depth below water-level; nevertheless the primary ore will be of very siliceous type. In another place in this report the vertical sequence of the minerals has been described.

A few analyses of Gladstone ore sold to the Great Cobar Limited are here reproduced. The parcels aggregated several hundreds of tons in weight. A and B represent picked ore, while C and D represent average ore, of which about 1,200 to 1,500 tons appear to be blocked out.

ASSAYS OF GLADSTONE ORE BY GREAT COBAR.

	A.	B.	O.*
	per cent.	per cent.	per cent.
Copper ...	15·27	18·90	63·20
Iron ...	6·28	11·43	6·72
Insoluble ...	62·70	47·95	about 26·04 per cent. sulphur.
Alumina ...	·63	1·27	......

	C.	D.
	per cent.	per cent.
Copper	7·57	6·00
Iron...	6·69	6·18
Insoluble	73·00	79·20
Alumina	1·44	·77

It will be seen at once that this typical secondary ore is highly siliceous, having an excess of about 70 per cent. silica in the average ore. This matter is considered in an appendix.

Prospects.—Until the primary ore shall have been reached, it is impossible to definitely state the real value of the mine. It may be safely considered that the influence of descending waters containing free oxygen will be found down to a depth of about 400 feet from the surface. Water-level occurred at a shallow depth in this mine, namely, 200 feet. At present the water is coming in on a "floor" at a depth of 260 feet, at the rate of about 100,000 gallons a day. In the Great Cobar the average of the ore above and at water-level was about 25 per cent. copper, while the value of the primary ore (commencing at about 400 feet from the surface) is only 2·5 per cent. copper.

* O is a block of chalcocite, about 80 lb. in weight, from 210 feet depth, encrusted with carbonates. Analysis carried out at Departmental Laboratory.

According to the scanty records extant of the Chesney, it appears that secondary (carbonate) ore of the upper levels averaged 6 per cent. copper, and that this passed down, in the primary zone, to copper pyrites, averaging somewhat less than 3 per cent. copper.

The channel at present worked in the Gladstone is extremely narrow, and represents one plane of exceptional weakness in a fairly wide zone of alteration. Cross-cuts are conspicuous by their absence; but in ore-bodies such as those found in the Cobar field, cross-cutting or diamond-drill boring is necessary, so as to prospect the zones of crushing in which a specified ore deposit may occur. Such tiny cross-cuts as do exist on both the 210 and 260 feet levels of the Gladstone, positively show that the zone of ore deposition has not been proved over its entire width. The existence of distinct lines of gossan outcrops also demonstrates the necessity for cross-cutting at a depth. Moreover, there are lines of gossan outcrops both north and south of the Gladstone workings. Both the veins north of the main shaft and south of the present workings are deserving of a trial. About 400 feet south of the main shaft, veins of siliceous gossan may be seen (see main map), and this would form one point at which to put in a cross-cut, both east and west. Cross-cuts should also be not out from the present drives.

The attached section illustrates the method of working the mine.

Attached are the returns of the Gladstone Mine up to date. The mine was closed down temporarily during the latter portion of 1911.

PRODUCTION.

Year.	Ore.		Estimated Yield.		Value.
	Raised.	Sold.	Copper.	Silver.	
	tons.	tons.	tons.	oz.	£
1908	8	8	2	......	126*
1909	209	28¾	10½	91	455†
1910	300	210	28	......	1,204‡
1911	1,300	1,111	94	......	......
Totals ...	1,817	1,357¾	134½	not known.	not known.

* Inspector Polkinghorne's Rept., Ann. Rept., 1908, p. 95.
† Net return, gross value £600, Ann. Rept., 1909, pp. 46 and 107.
‡ Inspector Polkinghorne s Rept., Ann. Rept., 1910, p. 96.

CobarPeak Silver-mining Company.

The Peak Silver-mine lies along the zone of crushing which accompanies the Great Peak Fault. The main plane of dislocation hereabouts appears to have split into two, the intensity of movement passing 2 chains to the west, the argillaceous sandstones of the western wall being bent up against (strike almost east and west) the fault. The mine itself lies a short distance to the east of this junction of western sandstones and eastern crushed slate.

The following notes concerning the development of the mine have been obtained from the Annual Reports of the Department of Mines.

In 1906 Mr. Inspector J. Polkinghorne reported that the main shaft at the Cobar Peak Silver-mine had been sunk 150 feet during the year, making a total depth of 360 feet. A considerable amount of cross-cutting and driving also were carried out. The ore occurred as lenses or patches. A large amount of low-grade ore was in sight, but not of sufficient value to send away for treatment. During the year 204 tons of ore were sold, yielding 17 oz. of gold, valued at £70; silver, 6,059 oz., valued at £804; lead, 25 tons, valued at £475. This was a highly encouraging return.*

In 1907, 600 tons of ore were raised, of which 16, tons were sold to the smelters. This parcel contained 5,600 oz. silver, 29 tons of lead, and 15 oz. of gold, valued at £1,280. A considerable amount of prospecting work was also carried on.

Operations in 1908 were confined to prospecting, 100 feet length of levels being driven.

In 1910, 90 feet more of driving was carried out. The ore was still found to be patchy. 1,076 tons of crude ore were raised, and of these the Company "had 751 tons treated at the Great Peak stamp batteries, jigs, and tables. The product, together with the prill ore—making in all 25 tons—was sold to the Cockle Creek Company, the assay value being £832."†

During 1911 a little prospecting work was done. Among other exploratory work 57 feet of cross cutting were carried out, but nothing of value appears to have been found. This lode is near the Great Peak Fault and is worthy of prospecting.

The outcrop was a ferruginous gossan, a few feet in width. At and above a depth of 150 feet, a rich brown and black gossan occurs. This contained traces of lead, vughs with chloride of silver, while at a still lower horizon galena occurred in large bunches.

Assays of some ferruginous gossans donated to the Department of Mines have been assayed at the Departmental Laboratory, with the following results :—

[3989-II.]—Gossanous Clayslate.

Gold	A trace.
Silver	25 oz. 9 dwt. 14 grs. per ton.

[3990-II.]—Sooty Pyrites.

Gold	A trace.
Silver	10 oz. 14 dwt. 20 grs. per ton.
Copper	40 per cent.

[3991-II.]—Galena.

Gold	A trace.
Silver	14 oz. 14 dwt. per ton.

The plan illustrates the method of working the ore body. Four levels exist at depths from the surface of 100, 208, 258, and 350 feet, respectively. No. 2 level (208 feet) is, approximately, 105 feet in length, driven about north 20° west.

A drive south at 233 feet is about 85 feet in length. No. 3 level (258 feet) is 110 feet, and No. 4 level (350 feet) about 145 feet in length. A cross-cut west at 350-feet depth has been driven for 100 feet. Three stopes have been put up, two on the 208-feet level (one north and one south of the shaft), and one on the 258-feet level.

A lead body (galena) was worked at the 238 and another at the 258 feet levels. On the 238 feet level, the south lens had a maximum width of 12 feet and a length of 60 feet. The northern lens was not so wide, but was also 60 feet in length. The average width of these lead bodies was about 6 feet.

At the 258-feet level both lenses showed lead carbonates. An interesting occurrence is reported below the 250-feet level. Whereas at both 208 and 258 feet depths the lenses were mainly of galena, leached gossans are recorded from depths greater than 275 feet.

* Ann. Rept., 1906, p. 95. † Inspector Polkinghorne, Ann. Rept., 1910, p. 97.

In the northern drive, at the 350 feet level, the prospectors appear to have driven away from the lode, and to have gone into country.

Attached is a copy of the principal returns from this mine* :—

Date.	Ore raised.	Ore sold or treated.	Yield.			Value.
			Gold.	Silver.	Lead.	
	tons.	tons.	oz.	oz.	tons.	£
1906	....	200	17	6,059	25	1,349
1907	600	167	15	5,600	29	1,280
1908	No ore raised for smelting.					
1909	No returns.					
1910	1,076	751	......	... .	......	832
Total	1,676	1,118	32	11,659	54	3,461

Burrabungie Mine.

Situation.—Between Cobar-Chesney and Mount Pleasant shafts.

History.—A patch of promising ferruginous gossan attracted notice, and two Irishmen sank a shaft on the same, and named it the Gladstone, after the statesman of that time. That was from twenty-five to twenty-eight years ago.

In 1897, copper was met in sinking, and in 1900 the Cobar Phœnix Company was formed to take over the conjoint properties of the Burrabungie and Cobar Smelting and Exploration Company, Limited.

"A fair amount of development has been done; the main shaft sunk to the depth of 300 feet, and cross-cut east some distance, showing a strong lode formation, in which occur narrow shoots or veins, carrying a high percentage of malleable copper.

A syndicate was formed to develop this mine, erect a smelting plant, and buy ores from the different mines."†

An extract from Mr. Carne's "Copper Mining Industry" (1908, p. 208) is reproduced here also :—

> "The Phœnix (late Burrabungie) Mine occurs between Mount Pleasant and Cobar Chesney. So far there has been no output recorded either of gold or copper ore. A shaft was sunk 200 feet, close to the south boundary of the Chesney. A cross-cut west at 200 feet undercut a ferric oxide outcrop, passing through about 10 feet of iron pyrites, part solid, part mixed with slate, in which but little copper sulphide occurs. Above the sulphide level stains of copper are visible in the rotten slate country. A cross-cut from the Chesney main shaft across the strike of the Burrabungie pyrite land failed to encounter it, pointing to its probable existence as an isolated segregation. A cross-cut to the east cut a mullocky lode with films of native copper 30 feet from the main shaft."

The Fort Bourke Copper-mining Company.

M.Ls. 50A and 52, P.M.Ls. 66 and 67, Parish of Cobar.

The veins prospected occur near the junction of the Cobar red slates and the powerful argillaceous sandstones of the Fort Bourke belt and they lie in a wide zone of crushing. Mr. Booth, L.S., informs me that a small

* Ann. Rept. † Mr. Inspector D. Milne, Ann. Rept., 1898, p. 77.

dam situated on the line of lode, and about 10 chains north of the Fort Bourke shaft, was observed by him to have its surface lowered 1 foot in twenty-four hours. This lends support to the idea that the line of lode under consideration is situated along a powerful fault zone. The contact of the slates and sandstones marks the possible continuation of the Chesney line, and the Cobar Gold line parallels this at a very short distance to the west. The lodes may be expected to dip in the same direction as the Chesney and Cobar Gold, namely, at very steep angles to the east. The main shaft to the east was sunk to a depth of 103 feet vertical. Water was encountered in the shaft at a depth of 177 feet. At a distance of 180 feet in the cross-cut a crushed zone was passed through, containing a copper lode with abundant quartz. Two channels were found to exist here, separated by a "horse" of slate 13 feet in width, the channels themselves being said to be each 2 feet in width. From this position in the cross-cut the prospectors drove about 20 feet along the two channels in both north and south directions. At a point 4 or 5 feet along one of the southern drives, a winze was put down to a depth of 59 feet. Prospecting operations at this depth were hampered with heavy water.

A new vertical shaft has been sunk to catch the top of the winze (174 feet below the surface). In December, 1910, the shaft was 110 feet deep, and from a point 80 feet below the surface it had been sunk through a cupriferous formation.

For the notes here reproduced, the Writer is indebted to the courtesy of Mr. J. Duffy, of Cobar.

Mr. J. Polkinghorne, in a letter to the Writer (5th January, 1912), describing the work done recently at this mine, says:—

> "The shaft (new) was sunk 174 feet, and holed through to winze; winze, 59 feet deep. The cross-cut east from the old shaft was put out 45 feet; no values met with. The reason assigned for cessation of work is that water rose over 100 feet."

East Cobar Mine.—Like the Fort Bourke Mine just described, this locality appears to be a promising place for prospecting. It is on the same line as that of the Fort Bourke, just described. It lies at the contact of the slates and dense argillaceous sandstones, and in a powerful zone of crushing. The mine was closed down during the Writer's visit to Cobar. The report of Mr. Carne* is here reproduced:—

> "In freehold of Great Cobar, Limited, in P.G.Ls. 46 and 47—[Also P.G.L. 52, apparently.—E.C.A.]—on the strike of the Fort Bourke (Cobar Gold-mine) line of lode, and in a direct line with the Cobar Tharsis Mine.
>
> "At time of inspection, in 1907, the prospecting shaft was down 100 feet, and a drive was being carried north at that level. A second shaft was being sunk a short distance north in P.G.L. 46. Practically little more than traces of copper had so far been discovered. Shaft 130 feet deep in July, 1908. No fresh developments."

East Cobar Freehold Mine.—This lies near the main Nyngan–Cobar railway line, at the margin of the alluvium. It occurs at the contact of the dense argillaceous sandstones and slates in a zone of dislocation, which can be traced to the south directly through the East Cobar, the Fort Bourke,

* "Copper-mining Industry," 1908, p. 216.

and the Cobar Gold Mines. The mine was closed down early in 1910, and the workings were not accessible during the visits of the Writer to the district. Mr. Carne's notes are here reproduced :—

> "No outcrop other than ferruginous slates. On direct line of Fort Bourke–Tharsis lode the strike is north 10° to 12° west. Copper first struck in the adjoining East Cobar Mine, closed down.
>
> "No sign of lodestuff above 70 feet level, when carbonates and grey ore appeared on west side of shaft, and gradually widened to about 4 feet at 130 feet. The actual width of the cupriferous belt had not then been proved, cross-cutting being necessary. A little gold can be panned off from the rubble. The copper ore occurs as an impregnation in slate country. . . . Engine, boiler, and poppet-heads were being installed towards end of 1907.
>
> "A sample of best selected ore yielded :—
>
> No. 07–7,426—
> Copper, 7·75 per cent..
> Gold, a trace } per ton."*
> Silver, 1 oz. 12 dwt. 11 gr. }

The accompanying additional notes on this mine are based upon notes supplied by Mr. J. Duffy, Cobar. The mine was prospected for gold, copper, and silver. A promising outcrop of crushed material led to the area being tested. A vertical shaft was put down for 140 feet. Water level was met at 118 feet, and the pumping plant erected was practically unable to cope with the water. (This strong water circulation at a shallow depth, in a flat and sub-arid country, is suggestive of a zone of crushing or dislocation.) Copper was found at a depth of 71 feet, and 120 feet below the surface the channel was 6 feet wide. The copper minerals found were blue and green carbonates and grey sulphides. At 120 feet depth a drive was put in about north 20° west for a distance of 50 feet. A drive in direction south 20° east was also put in for a distance of 30 feet. These distances are only approximate. A cross-cut was put in east and west at a depth of 120 feet for a total distance of from 60 to 70 feet. The lode had a slight underlay towards the east.

Tharsis Mine.—This mine has been worked under various names. It is now known as the Cobar–King George Syndicate. In 1908 Mr. Carne† made a report on this mine :—

> "Cobar Tharsis, about 1 mile north of Cobar, and apparently on the strike of the Fort Bourke (Cobar Gold-mines) and East Cobar lode, viz., north 10° to north 15° west, known also as the Ivanhoe and East Cobar Copper-mine Extended.
>
> "Under the latter title aid was granted (P.B. 2,743–05) to drive along the lode 100 feet, and to cross-cut east 20 feet at the 307 feet level.
>
> "Later the property was disposed of to the Cobar Tharsis Company, No-Liability.
>
> "Shaft deepened to 350 feet in November, 1906, after which work was suspended. No payable ore was disclosed. The little raised was of a very poor, siliceous nature."

Mr. Carne's conclusion that the lode under consideration was "apparently on the strike of the Fort Bourke and East Cobar lode," is doubtless correct. The methods employed by the Writer in this connection, in the absence of a continuous outcrop from the Freehold to the Tharsis (the long stretch of

* "Copper-mining Industry," 1908, pp. 216–217. † "Copper-mining Industry," p. 210.

intervening country being covered by alluvial flats and waste sheets) was to establish the existence of the slate and argillaceous sandstone contact and its accompanying zone of crushing on the northern side of the Nyngan–Cobar railway line. Further than this, it was necessary to show that the Tharsis Mine was both on the main line of direction of the Cobar Gold–Freehold line, and near the contact of sandstones and slates, if a close relationship were to be shown for the Tharsis with the more southern mines mentioned. The surface relief of the area is very slight, and outcrops are conspicuous by their absence; nevertheless, the argillaceous sandstones, with their characteristic eye-like structures, were found within 100 yards to the east of the Tharsis line, while the lode itself was of siliceous nature, and occurred in a series of well-cleaved slates. Traces of crushing were not uncommon. The line of strike of the Fort Bourke–Freehold vein is also practically collinear with that of the Tharsis. Moreover, the peculiar sandstones which form the eastern wall of the Freehold, East Cobar, and Cobar Gold were not observed to the west of the Tharsis Mine. It may therefore be safely concluded that the Tharsis lode is a northern continuation of the Fort Bourke–Freehold line. A mile beyond this point neither trace of augen-sandstone nor lode was found.

In 1910 a small company was formed in Cobar to work the upper portion of the lode. In the *Australian Mining Standard* for 10th January, 1911, p. 66, the following note occurs:—

> "The Cobar King George Syndicate, late Tharsis, appears to be on the eve of striking something substantial. A block of lode formation containing yellow ore, and splashed throughout with galena, has been taken from the bottom of the winze, started at the 230 feet level, down 30 feet. It is supposed to be the cap of a lode, and is widening out."

Under date 5th January, 1912, Mr. Inspector J. Polkinghorne wrote concerning this mine:—

> "*Re* Tharsis, or, as it is now known, the King Edward, the work there consists in driving north at the 300 feet level. The lode was not at all defined; there was just one small seam of black ore and quartz, with a little sulphide of iron on faces in slate."

Mr. Polkinghorne also stated that in these later workings the copper contents were very poor.

South Occidental Mine.—This was formerly known as the Great Cobar Gold-mining Company, or Hartley's lease. It adjoins the Occidental Gold-mine leases to the south. Prospecting has been carried on here, both at the contact of the sandstones and the slates, and in the slates also to the west of the contact. Nothing of value has been found.

Great South Peak Mine (Gold).

G.Ls. 60, 61, and 151, Parish Cobar.

The mine under consideration occurs along the same zone of crushing as that which has been determined by the Great Peak fault. Slate country occurs on both sides of the lode. The strike is about north 17° west, and the dip is very high, the lode inclining to the east, but being almost vertical.

The mine is worked by means of a vertical shaft, 240 feet in depth, and by means of five levels.

No. 1 *Level* is 100 feet deep, and consists of a drive to the south, approximately 50 feet in length, with a cross-cut thence of 35 feet to the east.

No. 2 *Level* is 113 feet deep, and the drives have been put in from a cross-cut, distant about 3 feet east of the shaft. The northern drive is 132 feet long, thence a cross-cut was put out west for 40 feet and east for 35 feet. At the end of the western cross-cut two quartz reefs were passed through, each being almost vertical and separated by a " horse " of slate. On the east side of the east vein a formation, 3 feet in width, of crushed chloritic slate was found. Its values are unknown.

No. 3 *Level* is 150 feet deep. The south drive is 50 feet long, and at 36 feet in the drive a quartz cross " leader," 20 inches in width, was cut. Coarse visible gold was contained therein. The dip of the cross-vein is about 65° in a N.N.E. direction. In crossing the main channel this cross-vein appears to have been enriched. The main channel is very narrow, with a zone of altered slate country up to 4 feet wide, and its footwall underlays to the east at an angle of about 8 degrees from the vertical.

Another cross-cut was put in at 40 feet along this drive for 20 feet to the west. At the end of the drive (50 feet) a cross-cut was put in for 30 feet to the east.

The northern drive is approximately 50 feet in length, and a cross-cut has been put in from the drive near the shaft to the west for about 50 feet.

No. 4 *Level* is 190 feet deep, and consists of a drive put in for 50 feet to the north.

No. 5 *Level* is 240 feet deep. In sinking the shaft from 190 to 240 feet a narrow leader, from a half to an inch in width, was followed. This is said to have yielded 2 oz. gold per ton of ore. From the foot of the shaft a drive was put in for 200 feet to the north. At the end of this drive a cross-cut was put in west for a distance of 14 feet, and this work revealed the presence of many small quartz " leaders " which yielded fair prospects of gold. A cross-cut was put in for 25 feet to the east from the shaft, and for 50 feet to the west from the shaft. From the quartz leaders cut in this work fair prospects for gold were reported. The drive to the south was 10 feet long in November, 1910, and was being extended, Government aid for 50 feet of driving having been recommended.

The following assays were made at the Departmental Laboratory. Nos. 1 and 2 represent samples taken from the 150 level by the prospectors :—

No. 1.—Gold per ton,		2 oz. 1 dwt. 9 grs.
No. 2.—	,,	1 oz. 12 dwt.
No. 3.—	,,	15 dwt. 6 grs.

No. 3 analysis is from a formation 10 feet wide in the eastern cross-cut near the shaft at the 113 feet level. Singularly enough the stone vertically above this in the No. 1 level gave a return of only 3 dwt. gold per ton.

The Perseverance Shafts.—These were put down on G.L. 61, to test the zone of crushing lying to the north of the Great South Peak. A strong vein of quartz, with a slight underlay to the east occurs immediately to the west, and the slates eastward of the quartz appear to have also suffered from crushing. The area prospected adjoins the Great South Peak block to the north. Nothing of value resulted from this work.

Several other shafts were put down along the same line of crushing in M.T. 4, P.G.Ls. 8, 9, and 54, about 45 chains N.N.W. of the Great South Peak shaft. Two of these shafts must have exceeded 200 feet in depth. A considerable amount of cross-cutting and other prospecting work appears to have been carried out, but without payable results.

The Premier Gold-mining Company.

G.Ls. 42 and 44, Parish Cobar.

The area leased by the holders of this mine has been prospected by several shafts. The vein lies in the northerly continuation of the zone of crushing, which contains the Blue Lode, the latter belonging to the Great Cobar, Limited. The country to the immediate west consists of crushed grey slate, while that to the east consists of well bedded but crumpled and faulted bluish-green argillaceous sandstones and sandy slates. The gold occurred in quartz and associated altered slate.

"The Premier Gold-mining Company at the Peak put down a new shaft to a depth of 167 feet. Work was also carried out from the old shafts, but nothing encouraging was met with." *

"The Premier Company raised no ore during the year, efforts being directed to the sinking of the shaft on the boundary with the Peak freehold. A depth of 108 feet had been attained at the close of the year, and it is stated that the shaft is to be continued to 300 feet."†

Nothing beyond the work here recorded appears to have been done at the mine.

The Lady Greaves Lode and The Peak Prospecting, No-Liability.

The mines described under this heading were not accessible, as to their underground workings, during the Geological Survey of Cobar, and the following description is based upon notes kindly supplied by Mr. T. E. Farquhar, of Cobar.

The little remaining Crown lands existing at The Peak in 1889 and 1890 were taken up as The Peak Prospecting Area about 1889 or 1890. Mr. Harry Cornish had found gold at The Peak during the seventies. At a later date (1894) an old prospector named Peter Andrews had examined the hill. In the following year Messrs. Barrass and Conley also prospected the private land on The Peak. In that year also Mr. J. Conley, of Barrass and Conley, found the well-known Blue Lode. Peter Andrews then went to the Tinto and prospected that block with Gardiner.

The Peak Prospecting, No-liability, was taken up by Messrs. T. E. Farquhar, Morris Reidy, James Crow, John Crow, and D. Mulway. Prospecting was carried on for a considerable period, and a crushing was obtained. Then the mine was examined by an engineer from Ballarat. Two tons were taken by him for treatment. The total gold contents of the stone, according to this authority, were 10 dwt. per ton, and arsenical pyrites was also present in quantity. In later years the Company decided to use an old Huntingdon mill, but only recovered 3 dwt. of gold per ton from a parcel of 50 tons. A considerable amount of arsenic was present.

At a later date a parcel of the stone was sent to Eaglehawk, in Victoria, for analysis. The arsenical pyrites had grown more pronounced with increasing depth, but the gold contents had improved, being 1 oz. per ton. By the old chlorination methods this was unpayable. The mine was then abandoned by the Company, and taken up subsequently by other prospectors, but with unpayable results.

The Lady Greaves was tested to a depth of 290 feet by shafts and winzes. Water level was not reached. The vein proper appeared to be of quartz and pyrites, but according to Mr. Farquhar the gold contents occurred in the

* Ann. Rept., 1906, p. 11. † Ann. Rept., 1907, p. 13.

slate country rather than in the solid quartz. The Lady Greaves and The Peak Prospecting Area were on the same vein, the former being the more northerly mine of the two.

It may here be added, in addition to Mr. Farquhar's notes, that these two mines appear to lie on the same line of dislocation as the Premier and Blue Lode mines, such line of dislocation being apparently a subsidiary movement of the Great Peak Fault.

"Messrs. Cameron and Cooper are prospecting the Lady Greaves lode on the north-east side of The Peak, and can get a few colours of gold in a strong reef."*

The Lucknow and The Wild Wave.—The former of these mines lies about 6 miles and the latter about 4 miles from Cobar in a N.N.E. direction. The Lucknow has been prospected for gold and silver, and the first-named mineral has been found in a large siliceous outcrop traversing the lease. The country consists of conglomerates, quartzites, sandstones and claystones. The conglomerates are not well compacted, and the sediments are possibly of Devonian age. No fossils, however, have been found whereby the age of these beds could be definitely known. The dips of the sediments are high, and average about 78° in a direction north 80° east. Two shafts were sunk, the main one being about 200 feet deep. Nothing of value appears to have been found.

The Wild Wave shafts were also sunk in country similar to that of the Lucknow. A great deal of prospecting has been carried out here, but nothing of value was found.

Royal George.—Portions M.Ls. 7 and 10, Parish Mopone, County Robinson.

Country of conglomerates, sandstones, quartzites, and claystones. The outcrop prospected is in the nature of a long iron-stained siliceous mass, possessing a strike of north 15° west. Prospecting was carried out for gold and lead by means of a vertical shaft about 125 feet in depth. Nothing of value has been recorded from this mine.

Cobar Weltie.—Portions M.Ls. 1 and 2, 40 acres, Parish Weltie, County Robinson, 8 miles south-east of Cobar.

The country consists of iron-stained slates and quartz. A shaft was sunk here 150 feet deep on an ill-defined ironstone outcrop. No driving was carried out, and nothing of value was found.†

Coronation Mine.—M.Ls. 4 and 6, Parish Weltie, 7 miles south-east of Cobar. The lodes are of quartz, which form strong outcrops in a country of well-cleaved slate. The lodes under consideration have been worked by different parties. A shaft 100 feet deep was put down on one reef, and good gold thence was reported. Another vein occurs about 20 yards further to the west, and on this a shaft was sunk vertically, the lode having a very slight underlay. At the close of 1910 this shaft was about 217 feet deep, and the length of the workings from the shaft was about 110 feet. Gold was the mineral sought. The westerly lode has a strike approximately N.N.W., and it can be traced for a considerable distance along the surface. The present workings are about 60 yards to the N.N.W. of the old Coronation shaft. Encouraging prospects are reported at various times.

The Beechworth Veins.—These lie about ½ mile to the S.S.E. of the Coronation Mine, and appear to be intimately related to those of the Coronation. The occurrence is either that of a branching quartz vein or as two

* Inspector Godfrey, Ann. Rept., 1900, p. 102. † Mine Records, 1908.

closely-related veins which diverge in a southerly direction. The outcrops are strong for distances of from 15 to 20 chains, and the country consists of prominent outcrops of well-cleaved Silurian slates of reddish and greyish colours. The strike is approximately N.N.W., as observed over a distance of 400 yards. A shaft 262 feet deep has been sunk on the outcrop at the southern point of the slate ridge. A considerable amount of driving and cross-cutting has been carried out. Gold and silver were the minerals sought. The prospecting results appear to have been disappointing.

The Central.—M.Ls. 7 and 10, Parish Weltie, County Robinson, about 10 miles from Cobar, along the old Nymagee-road.

A vertical shaft has been sunk over 300 feet. Only infinitesimal traces of copper were discovered in quartz."*

The occurrence consists of quartz veins in well-cleaved slates. Strike N.N.W. and S.S.E. Length of outcrop, 500 feet. Gold, silver, and copper were the minerals sought.†

The **Mallee Tank** *and* **Conqueror** *Prospecting Shafts,* M.Ls. 8 and 9, Parish Weltie, County Robinson, about 11 miles south-east of Cobar.

The shafts under consideration occur in a formation of calcitic limestone, dense sheared conglomerates, slates, and peculiar breccias and quartzites. The limestone contains corals of Silurian age. These sediments in places dip to the east at high angles, at others to the west; while in the vicinity of the mines the rock dips are almost vertical. It is probable that faulting action has taken place in this locality.

During the visit of the Writer in 1910 the shafts had fallen into disrepair, and examination of the workings was not possible.

The accompanying description is extracted from Mr. Carne's "Copper Mining Industry, 1908," p. 210:—

"Limestone was struck in each of these; a sample from the latter gave the following composition on assay:—

[No. 7431-07.]	Per cent.
Calcium carbonate	97·10
Ferric oxide and alumina	·54
Gangue	2·12
Magnesium carbonate, and undetermined ...	·24
	100·00 "

Ten miles south-west from Cobar, and 3 north-west of Queen Bee Mine. Inspector J. Polkinghorne reported (P.B. 1363-07):—

"Slate with quartz veins, carrying strong stains of copper carbonates; country strongly impregnated with iron oxide. Aided to sink a shaft 350 feet, and drive 200 feet north and south from bottom.

"At 310 feet heavy water prevented continuation of shaft with prospecting appliances; cross-cutting began; the first 36 feet of the cross-cut was through a lode of very low grade, a little copper showing in places, and small veins of pyrites."

Great Cobar Extended.—A name given to a small prospecting claim about 1 mile south of the main shaft of the Great Cobar, Limited. The country is of slate; a small siliceous gossan outcrop traverses the lease, upon which a shaft 100 feet deep has been sunk, in the hope of finding the southern extension of the Great Cobar lode. Only negative results were obtained.

* J. E. Carne, "Copper-mining Industry," p. 210. † Mine Records, 1909.

The Leslie.—G.L. 1, Parish Mullimut, County Robinson, about 8 miles N.N.E. from Cobar.

The Leslie outcrops as a long and powerful line of quartz which has been prospected in various spots for gold. The country consists of ironstained slates or claystones of undetermined age.

In 1910, Mr. D. Penhall commenced a prospecting campaign, and received aid from the Prospecting Vote to sink and drive.

By the close of 1910 the vertical shaft was 175 feet deep, and cross-cuts and drives to the extent of 50 feet had been put in.

The following extract is from a letter to the Writer by Mr. Inspector Polkinghorne, under date 5th January, 1912 :—

> "The Leslie is about 260 feet deep. The drives are about 50 feet north and 50 feet south at the 100-feet level. A cross-cut 12 feet long occurs at the 100-feet level, and another one 20 feet long at the 145-feet level."

Louth Road *Outcrops.*—These consist of long and wide irregular masses of siliceous limonite found near the 8-mile peg on the Cobar–Louth road. The country consists of sandstones and shales exhibiting no traces of cleavage, and which have been placed provisionally among the Devonian sediments. Several shafts were sunk on the outcrops, one or two of these workings being apparently of considerable depth. A conspicuous feature of the spoil heaps lying about the shafts was the white colour of the raised rock, suggesting thereby that the iron contents of the sediments were only superficial. Nothing of permanent value appears to have been found.

Mr. J. B. Jaquet reported as follows on this occurrence :—

> "I was informed by Mr. W. J. Hogan, of Cobar, who accompanied me during my inspection, that 10 tons of the ironstone yielded, when treated in Cobar, gold at the rate of 16 dwt. per ton."*

APPENDIX I.

Occurrence of Magnetite or Pyrrhotite in Ores from New South Wales, and Periods of Vein Formation in the State.

The association of pyrrhotite, magnetite, and Ekmannite with copper, gold, and silver ores in New South Wales is so interesting when the absence of igneous rocks from the locality is considered, that it has been considered advisable to make a record of all the localities known officially in New South Wales in which any or all of these interesting minerals occur in association with ore deposits, and furthermore to state briefly the nature of the occurrence. In each case it will be seen that only the contorted Palæozoic sediments contain such minerals, and that in each case the ore deposits from which they have been derived appear to have been subjected to profound erosion. It will be seen that in some cases magnetite is evidently a mineral produced at the contact of an igneous rock and a sedimentary formation, while in other cases there is no evidence of the presence of igneous rocks for a distance of many miles from the deposits. In all, the geological associations point to the action of great heat in their production, either by reason of the depths at which they were formed or by reason of the presence of igneous rocks at whose contacts with other rocks they occur.

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* Ann. Rept., 1895, p. 175.

The majority of the references are from "The Copper-mining Industry," by Mr. J. E. Carne. Information has also been supplied by two others of my colleagues, Messrs. G. W. Card and M. Morrison, as to localities and age of the rocks.

1. *Allen* (*Mount*).—10 miles north of Mount Hope. Magnetite and hæmatite in Palæozoic slates (Silurian ?), near intrusive quartz-felspar porphyries. Mineral sought, gold.

2. *Anaconda Mine.*—About 30 miles northerly from Condobolin railway station.

"The country consists of ferruginous slate and much crushed conglomerate."

"Magnetic iron is present in bright micaceous particles, which may be confounded with copper glance."*

No mention of igneous rocks occurs in Mr. Carne's report.

The sediments appear to be either Silurian or Ordovician.

3. *Attunga.*—9 miles easterly from Attunga railway station.

Country rock limestone and andesite. Minerals, such as copper silicate, garnet, and iron silicate in "contact" lode. Age of sediments apparently Devonian. The Attunga occurrence is here mentioned because of the presence of iron silicate. (Silica, 73 per cent.; iron, 15 per cent.)

4. *Broula.*—14 miles south-west of Cowra. Country of diorite, intrusive into slates and limestones. Contact deposit. Minerals, copper ores and magnetite. Age of sediments, Silurian or Ordovician.

5. *Bullen* (*Mount*).—Queanbeyan district. Country, amphibolite dyke in felsite and syenite. Copper ores occur with magnetite.

6. *Burraga Copper-mine.*—40 miles south of Bathurst. Country of talc schists and quartz porphyry. Copper ores here occur with iron pyrites and magnetic pyrites. Possible age of sediments, Ordovician.

7. *Cadia Copper-mine.*—About 15 miles south-west of Orange. Country of andesite. Copper ores with magnetite (specimen in Departmental Museum). Mr. Carne records pyrites and specular iron. He also says, "The anhydrous form of the iron oxide (specular iron) is unlike surface oxidation" (p. 129.) Age of country, Ordovician (?).

8. *Cobar Mine.*—Silurian slates and sandstones. Copper ores, with magnetite, pyrrhotite, and Ekmannite. No igneous rocks present. Heavy faulting action in contorted rocks prior to ore deposition. Ore deposits occur as replacements along planes of dislocation.

9. *Coombing Park.*—About 2 miles south-west of Carcoar. Country of slate ("killas") and "elvan," possibly Ordovician in age. Copper ores with hæmatite and magnetite.

In Mr. Carne's report there is no mention of igneous rocks, although the presence of garnets and of "five hummocks (of from 20 to 50 or more acres each) of a very rich compact hæmatite iron, much of it magnetic," would suggest a "contact" or alteration deposit by igneous intrusions.

10. *Cow Flat.*—13 miles south of Bathurst. Limestones and schists apparently of Ordovician age. Copper ores associated with chlorite schist and magnetite. Granite outcrops occur 2 miles to the north and 4 miles to the east.

11. *Cowley.*—Queanbeyan District. Limestone and granite country. Copper ore with abundant magnetite. Sediments of Lower Palæozoic age.

12. *Dolcoath Lode.*—Near Yeoval, county Gordon. Copper ore in granite, associated with magnetic iron (magnetite).

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* J. E. Carne, *op. cit.*, p. 269.

13. *Goodrich Mine.*—Yeoval. Copper ore associated with quartz and magnetite in granite. Age Palæozoic ; probably Silurian.

14. *Gumble.*—About 4½ miles from Manildra railway station. Tin and copper ores associated with magnetite "at the junction of granite and altered Silurian slates" (p. 145).

15. *May Queen Lode.*—Gilmore Range, Clarence River. Copper ores, associated with magnetite, specular iron, garnet, and hornblende in diorite and limestone country. Contact deposit, apparently closing Permo-Carboniferous in age.

16. *Mudall.*—Bogan River, Trundle Division. Copper silicate in association with magnetite. No record of country rocks. Probably a contact deposit because of association of copper silicate and magnetite.

17. *Murrumbidgee Copper-mine.*—County Harden. Chalcopyrite, associated with magnetite in granite.

18. *Pine Hill.*—13 miles from Molong Railway Station. Copper ores, in association with garnet and magnetite at contact between granite and limestone.

19. *Sugarloaf.*—About 2 miles south of Blayney. Copper pyrites, in association with magnetite and pyrrhotite in andesite. Age of country, apparently Ordovician.

20. *Summerhill Mine.*—Rockley. Chalcopyrite, associated with pyrrhotite at a depth in schists and slates of Silurian or Ordovician age. No igneous rocks reported from vicinity.

21. *Tinley, A1 Mine.*—Parish Obley, county Gordon. Chalcopyrite, associated with magnetite in granite country.

22. *Willi Willi Mine.*—About 37 miles from Kempsey. Copper ores, associated with pyrrhotite, ordinary iron pyrites, garnet, and kaolin as a contact between sandstones and limestones, and a dyke-like formation of epidote and quartz. The sandstones and limestones are of Permo-Carboniferous age.

23. *Black Creek, Tabulam.*—Magnetite, at contact of granite and Permo Carboniferous sediments.

Of these, Nos. 2 (Anaconda), 8 (Cobar), 10 (Cow Flat), and 20 (Summerhill Mine) appear to exist independently igneous rocks. In these cases the containing sediments are older Palæozoic in age, and are so contorted as to suggest that the lodes now exposed were formed in the cores of great mountain ranges. That being assumed, the idea is suggested that the lodes were formed under conditions of great heat and pressure. Pyrrhotite, magnetite, and iron silicate occurrences may thus be explained in the absence of molten igneous masses. Nevertheless, if one pushes the reasoning backwards a step, it will be seen that there is not much real difference between the occurrence of such deeply seated ore deposits formed without visible connection with igneous rocks, and those formed at contacts of hot igneous rocks and intruded rock masses of any nature whatever. For if one assumes that the deep-seated ores, such as those of Cobar (formed without visible connection with hot intrusive bodies) are connected with lines of deep-seated dislocation and shearing, then one is forced to admit that vapours and solutions of minerals which may arise along such zones of crushing owe their origin to the emanation from the tapping of actual molten bodies at a depth or—what is more likely—to the emanations from a mass erstwhile solid under conditions of enormous pressure, but rendered plastic by the relief of pressure caused by the heavy faulting and crushing nearer the surface

It would be interesting to classify the various periods of ore formation into which the Palæozoic of New South Wales (or of Eastern Australia) may be divided. In the Mesozoic and Tertiary periods no lode forming appears to have been in progress. New England, as to its northern and eastern portions, appears to have been powerfully affected by mountain building and vein formations in the closing Palæozoic. No other portions of New South Wales appear to have been affected by this momentous movement, although Queensland appears to have been profoundly affected by it. Immediately to the south and west of New England, the Devonian appears to have been extensively intruded, and contorted with the production of strong lode formations. In south-eastern New South Wales the great mountain-making epochs and accompanying formation of strong mineral veins appear to have practically ceased with the close of the Silurian period; in other words, ore deposits are exceedingly rare in Devonian and younger sediments in this area of New South Wales. In the great Cobar district the ores are doubtfully referred to the close of the Devonian, and it may hereafter be proved that the ore formations there are of Lower Palæozoic age. Still further west, at Broken Hill, the ore deposits may be Cambrian, or even pre-Cambrian, in age. Roughly, then, we may say that areas of vein formation contracted as geological time progressed in East Australia in a direction as from south to north, until at the close of the Permo-Carboniferous all but insignificant vein-forming activities had died away in the area south and west of New England, while even that region has been unaffected by similar activities since the commencement of the Mesozoic; but in a northward direction it is possible that other strong vein-making activities have been in progress during still later times. For example, New Guinea, with its immense mountains, may have been subjected to the formation of mineral veins even in late geological time.

A careful study of the mineral associations, and of the geological features connected with these mineral groups of New South Wales, will doubtless allow a definite statement to be made in the future as to the geological age of each great period of lode-forming activities in that State. Already the age of certain mineral groups is known: thus, the great tin, wolfram, and bismuth deposits of New England occur in sediments of Permo-Carboniferous age and are in part overlain by early Mesozoic sediments; the Devonian rocks of Parkes also overlie the Ordovician rocks, in which latter occur the gold deposits; while the associated Silurian rocks have never yielded any ore deposits up to date.

APPENDIX II.

NOTE on the relation of Topography to Ore Deposits in New South Wales.

It is now coming to be recognised that the wild topography of eastern New South Wales is of very recent geological age, possibly only dating back to the close of the Tertiary period, while the actual surfaces of the plateaus, and the long rolling plains of denudation in the central and western portions of the State are of considerable geological age. It is recognised, also, that the larger copper, gold, and silver replacement bodies are to be found rather in the older than in the younger Palæozoic sediments. That being the case, it might be expected that ore bodies outcropping on old plains of erosion in regions of sub-arid climate would—all other things being equal—exhibit large bodies of secondarily enriched ore, while ore-bodies outcropping in areas of wild topography—particularly at the bases of deep cañons in regions of abundant rainfall

—would tend to have a very shallow water-level, and to possess but a limited amount of secondarily enriched ore, inasmuch as much of the contents of the ore would be washed away from the lodes instead of being dissolved and gradually sinking downwards to enrich the lode at and near the zone of permanent saturation.

If one now turns to the evidence of the mining fields themselves, he will find material for consideration. It is a well known fact, in the wild topography of the North Coast of New South Wales, that the water-level is close to the surface, that the surface shoots were payable but small, and that at very short depths the lodes were all abandoned. A similar condition of affairs is known to exist, both in the wild topography of the South Coast and on the rough western slopes of New England. On the other hand, at Nymagee, Mount Hope, Cobar, Canbelego, and Broken Hill, huge masses of enriched ore occurred, the mining of which caused the growth of considerable towns. Wyalong, with its rich patches of secondary ore, belongs also to the sub-arid plain region, while Hillgrove belongs to the plateau, the gorge which cuts into the old plain having only just commenced its work of destruction.

APPENDIX III.*

Suitability of Cobar Ores, other than those belonging to the Great Cobar, Limited, for purposes of Smelting.

The ores of the Great Cobar, the Cobar Gold, the Cobar Chesney, and the Peak Gold Mines are all smelted together, the large bodies of basic ore belonging to the Great Cobar being used as a flux for the acid ores of the Cobar Gold, the Chesney, and the Peak Mines. The average working assays of these Cobar ores are approximately† :—

	A. Great Cobar Mine. per cent.	B. Cobar Gold. per cent.	C. Chesney. per cent.
Copper	2·60	1·30	3·50
Iron	40·40	9·00	12·00
Silica and insoluble ...	16·24	80·00	68·00
Alumina	6·50	2·8	8·00
Sulphur	11·20	......	......

It is evident, from a consideration of these assay values, that ores such as those of the Cobar Gold and the Chesney need a considerable amount of basic flux for their satisfactory smelting, and if fluxes had to be conveyed to them from a considerable distance they would need to possess high values to bear the costs of carriage entailed in the conveyance of fluxes. But, inasmuch as—

(*a*) The Great Cobar ore contains about 40 per cent. iron, and only from 16 to 22 per cent. silica and other insoluble material;

(*b*) Great Cobar resmelts its converter slag, and thus economises its basic cupriferous flux;

(*c*) The ore reserves of the Great Cobar exceed 2,000,000 tons, while those of the Cobar Gold are about 350,000 tons, and those of the Chesney are about 600,000 tons;

then, by a judicious mixture of acid and basic ore, so that allowance is made for sufficient iron to remain in the charge for the formation of a suitable slag, the highly acid ores of the Cobar Gold and Chesney can be smelted cheaply without any further outlay for outside fluxes.

* See, however, Appendix IV. † See *Australian Mining Standard*, 26th October, 1911, p. 419.

The Great Cobar, Limited, also undertake a limited amount of Customs Work. Naturally, in their desire to smelt the valuable acid ores of the Cobar Gold, Chesney, and Peak Mines, they are on the lookout for basic copper ores, while at the same time they are not desirous of treating ores which possess a decided excess of silica over that of iron. Excess of silica is generally penalised to the extent of 5d. per unit by them, while excess of iron is usually paid for at the rate of 5d. per unit. Mining companies such as those of the Budgerygar North, the Budgery, the Gladstone, the Young Australian, the Tharsis, the Tinto, and the C.S.A. have been in the habit of selling their ores to the Great Cobar; but, since the silica excess is heavily penalised, as already stated, and, moreover, as the "fines" which pass through a $\frac{3}{4}$-inch grizzly are rejected, and as these frequently contain some of the richest secondary ores (sooty sulphides, carbonates, and oxides), there is a desire on the part of certain mine-holders to amalgamate in part, and to smelt their own ores.

The notes in this Appendix make no claim to accuracy of detail, and are rather in the nature of suggestions, in which ideal conditions are assumed. In this way, one can understand the absolute dependence of the smaller Cobar mines upon a large central mine producing an abundance of basic flux, unless a different method of treatment be devised. This fact was strongly emphasised in 1899 and 1906 by Mr. J. E. Carne.* Being convinced of the great difficulty of obtaining remunerative results from the Cobar ore deposits (*outside* those controlled by the Great Cobar, Limited) *by ordinary* † *smelting methods alone*, the Writer has assumed a smelting campaign under the most favourable conditions for the district at the present time. In each case the minimum costs of freight, smelting, mining, and other items, are supplied. Thus the costs of smelting and converting ore are quoted from the Great Cobar returns—costs which no smaller company could hope to lower, or even parallel, seeing that huge tonnages are there dealt with (375,000 tons a year). Not only so, but the furnaces here are of the most modern type, and metallurgists of international repute are in constant attendance. It will be evident, also, as the notes are read, that the calculation of costs is not complete. Thus:—

(1) The redemption of capital and interest involved in any large smelting scheme is not brought forward prominently in this discussion, although it is a feature needing the most careful consideration. In ordinary types of investment, such as properties or railways, "if proper appropriation be made for maintenance, the total income to the investor can be considered as interest or profit." In mines, however, a portion of the income must be put out in sound investments to form a sinking fund by which the outlay of capital may be redeemed at the time fixed for restoration. "Mining business is one where 7 per cent. above provision for capital return is an absolute minimum demanded by the risks inherent in mines, even where the profit in sight gives warranty to the return of capital. Where the profit in sight (which is the only real guarantee in mine investment) is below the price of the investment, the annual return should increase in proportion."‡

(2) The question of realisation (say from £7 to £9 per ton of Blister Copper at Cobar) is not here considered.

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* "Copper-mining Industry," 1908. p. 202. † Reference is made on a later page to a simple concentrating and smelting scheme which might possibly be remunerative. ‡ Hoover, "Principles of Mining," 1909, p. 43.

(3) In the estimated cost of smelting one unit of silica at from 5d. here adopted, it must be remembered that such a charge for this treatment of silica is only possible where suitable fluxes are easily accessible in abundance, and where the installation is almost perfect. On the other hand, the cost of smelting a unit of silica at Cobar would probably exceed the limit here set, because of the great cost of suitable fluxes in that district.

(4) No attention has been given to the question of lime necessary for fluxing purposes.

No. 4 might possibly be cancelled by the assumption, in these notes, of a greater content of ferrous-oxide in the charges than would be necessary were a small percentage of earthy bases to be used with the iron. Nos. 1, 2 and 3, however, are all important.

Leaving aside, then, for the present, the considerations of redemption of capital, extra costs of smelting a unit of silica in such a district as Cobar, realisation, &c., it is evident that in considering such a question as the present it is necessary to take into account—

(*a*) The ore reserves, the average analyses of such ores, and the probable character and amount of the ore as yet undeveloped.

(*b*) The nature and cost of fluxes needed.

(*c*) The cost of smelting and converting a ton of neutral ore.

(*a*) *Ore Reserves.*—Without exception, these are small, unless one takes into consideration the C.S.A. ore-bodies, which are certainly large, but which are low in copper contents, and which might be considered rather as a cupriferous flux.*

In any discussion as to the amalgamation of the Cobar mines, the Queen Bee Mine may be left out of consideration, because it possesses its own smelters, and in 1911 there was a proposal on the part of the management to treat the ore of the mine by the mineral separation process preparatory to smelting in reverberatories. Moreover, unless railway connection be established between The Bee and Cobar the cost of freight would be considerable.

The Gladstone possibly has from 1,200 to 1,500 tons of ore developed between the 200 and 260 feet levels. The upper portion of this consists of rich sulphides and oxides of copper, with much native copper included, but at the 260-feet level the average ore assays made by the Great Cobar, Limited, are as follows :—

	A. Parcel about 70 tons.	B. Parcel about 50 (?) tons.
Copper	7·57	6·00
Iron	6·69	6·18
Silica	73·00	79·20
Alumina	1·44	·77

Parcels assaying 15, 18, and even 46 per cent. copper have been sold from this mine to the Great Cobar, Limited, but such class of ore is confined to the limited upper portion of the mine.

It is almost certain that the values, as shown in these tables, will decrease somewhat in depth, even at such slight depths as from 350 to 400 feet below the surface. A much larger body of ore than developed already may hereafter be exposed as a result of work carried out north and south of the present limits, but in the present calculation it is not safe to count on more than twice the actual ore exposed.

* See, however, Appendix IV.

The Young Australian.—Snelson and Party, working on tribute, in 1911, raised about 500 tons of ore for a return of 43·5 tons of copper—that is, for a return of 8·71 per cent. of copper. This ore came from the oxidised zone, and was obtained while sinking a winze (100 feet deep) from the 150-feet level and running drives thence north and south for distances aggregating about 60 feet. A considerable tonnage of good ore may be expected from the shoot thus partially developed, but at a depth exceeding 100 feet below water-level these values cannot be expected to be maintained. A reference to the history of the Chesney, Tinto, C.S.A., Great Cobar, and Cobar Gold Mines is sufficient to justify this statement.

The ore is acid. A fairly typical assay is afforded by the contents of a parcel of 70 tons treated by the Great Cobar.

Copper...	7·69 per cent.
Iron	8·00 ,,
Insoluble	66·20 (SiO_2 and Al_2O_3).
Alumina	1·50

In this analysis the copper percentage had better be altered to 8·71, namely, the percentage based upon yield of copper from treatment of 500 tons of ore.

The Budgery is distant 55 miles from Cobar—52 miles by rail, and 3 miles thence by road. The ore body is in the form of a pipe, possessing an inclination of about 45 degrees to the horizontal. Such ore as exists above water-level is rich and of the nature of a replacement body; below that level it appears to be unpayable. The ore reserves at the end of 1911 amounted to about 1,000 tons. Prospecting for other pipes of ore is in progress, but without success up till the present. The ore varies from 5 to 8 per cent. copper, as sold to Great Cobar.

The Budgerygar North appears to contain a basic ore assaying well in copper in the oxidised zone. Its extent is not known, because of limited development. Distant 14 or 15 miles from railway by road, and thence 52 miles by rail to Cobar.

The Occidental is a gold-mine with very low copper values. A tonnage of about 560,000 tons, won between the years 1889 and 1911, has been treated for a return of about 110,250 oz. gold, or a yield approximately of 4 dwt. gold per ton. This recovery of 4 dwt. is by no means a complete one, and for purposes of smelting it is doubtless better to consider that the Occidental ore contains from 5 to 6 dwt. gold per ton, or of a value of between £1 and £1 5s. per ton. The average tonnage between two levels 100 feet apart appears to be from 125,000 to 150,000 tons, if the whole lode be worked. Only picked stone appears to have been mined during 1911, and of this picked stone only about 125,000 tons appears to exist between the third and fifth levels.

Its acidity is pronounced, and may be put down approximately as the same as that of the Cobar Gold-mine, namely, 80 per cent. silica, or 71 per cent. excess of silica over that of iron. This is a conservative estimate of the silica excess.

The C.S.A. and the Tinto.—The problem of the C.S.A. and the Tinto ores is a complicated one, inasmuch as the copper values of the mines, considered as a unit, appear to be rather low to allow them to be worked alone on a large scale for that metal. Their silver and gold values are also very small.

The Tinto ore body as developed is not large (see plans and sections herewith), but near and just below water level a body of basic ore was won which yielded 244·5 tons of copper from a total of 3,994 tons of ore—that is, an average of 6·1 per cent. copper.

An average assay of this ore is here reproduced from the returns of the Great Cobar office :—

Copper	6·48 per cent.
Iron	34·29 ,,
Insoluble	14·30 ,,
Alumina	1·01 ,,
Sulphur	39·41

This is a good smelting ore, although the insoluble materia s rather high, and the sulphur is high. It is evident that the iron exists in great measure as iron pyrites, because of the high sulphur percentage. This ore may be expected to become poorer with increased depth—say, 200 feet below water level; but if it could be proved to exist in quantity it would form a splendid ore to flux in part the acid ores just enumerated.

The C.S.A. as developed consists of two basic ore lenses and a few narrow veins of acid copper ore lying still further to the east, the volume of which is not sufficient* to materially influence the tonnage of the two lenses of basic ore. A synopsis of the analyses of the two large basic ore lenses has been supplied by the Directors of the C.S.A. Company, and is here reproduced. In these analyses the copper contents have been omitted.

Approximate Average Assays of C.S.A. Ore (supplied by C.S.A. Company).

	Basic Ore.	Width.	S.	Fe.	SiO_2.	Zn.	Pb.	Al_2O_3.
Eastern Ore Body— No. 3 level (560 feet) S.E. cross-cut.	182 ft. 6 in. to 224 ft.	41 ft. 6 in.—8 samples of 5 ft. each.	35·2	26·3	8·3	16·6	7·6	..
,, ,, ..	244 ft. to 285 ft.	41 ft.—9 samples	28·7	27·5	28·6	4·9	1·5	..
South Drive, off S.E. cross-cut.	1 ft. to 132 ft. in basic ore.	30 samples	31·3	24·9	11·6	12·2	6·3	6·07
No. 4 level (660 feet) E. cross-cut just into basic ore.	....	1 sample, 4 ft. wide ..	39·7	31·6	14·6	3·0	..	8·80
Western Ore Body— Nos. 2 and 3 levels ..	Basic ore..	18 ft.—19 samples.. ..	39·1	38·5	5·3	3·0	0·65	..

An inspection of these analyses shows that this ore could be smelted quite cheaply. The unknown quantity is the copper content and there is a rather low excess of iron over that of silica. Two parcels, aggregating about several hundreds of tons, from this mine were assayed by the Great Cobar, Limited, with the following result :—

	A. per cent.	B. per cent.
Iron	35·74	35·39
Insoluble	7·55	7·70
Aluminia	2·84	1·74
Sulphur	35·44	37·30

From a comparison of these analyses with those furnished by the C.S.A. Company, it would appear that the ore here considered (A. and B.) has come from the western body, where the lead and zinc content is almost negligible. The copper values have not been supplied because they are misleading.

* See, however, pages 200-202.

An assay of a parcel of ore sold to the Great Cobar and won from the small acid eastern ore body yielded the following return :—

Copper	5·60 per cent.
Iron	16·07 ,,
Insoluble	48·00 ,,
Alumina	4·45 ,,
Sulphur	17·97 ,,

The copper values are good, but the tonnage from this vein would be very small compared with that of the large leaner basic bodies associated with it. Its silica percentage is also high. Moreover, its copper content may be expected to depreciate somewhat at a moderate depth below water-level

The gold and silver values are very low in this mine.

(*b*) *The Fluxes.*—The problem of fluxes in Cobar presents certain difficulties. In a word, the Cobar mines are not ideally grouped around any centre, and such centre when chosen is at a considerable distance from fluxes unless the C.S.A. Mine be adopted as the centre.

Iron oxide occurs near Mount Nurri, and would cost about 18s. per ton landed at Cobar. Partial assays of this flux used at the Queen Bee Mine have been supplied by Mr. A. E. Moore, legal manager to the company working that mine, and are as follows :—

Iron.	Silica.
58·5	23·1
44·3	16·0
55·7	15·0
48·4	14·0
48·4	16·2
47·5	17·4
45·0	23·5
48·4	15·0
51·5	12·4

Limestone cannot be obtained locally under from 15s. to £1 a ton unless a tramway be run out to the quarries 20 miles to the south. Partial analyses of this limestone gave a return of 99 per cent. carbonate of lime, or about 55 per cent. lime. Possibly limestone could be obtained from the Wellington district at about from 9s. to 12s. 6d. per ton—say 9s. railway freight and 2s. 6d. to quarry and place on railway trucks.

On the other hand, the C.S.A. and Tinto ore bodies may be considered as iron fluxes, and the ores of the Gladstone, the Young Australian, and other mines might be fluxed with the cupriferous pyrites of the C.S.A. ore bodies.

Let it be supposed that the smelter be erected at Cobar, and that the C.S.A. flux be brought to the smelter. Mining costs at the C.S.A. could scarcely be reduced below 10s. per ton. It may also be assumed that the railway connects up the C.S.A. Mine with Cobar, and that thus the freight on the flux be reduced to 1s. per ton, as against the present freight cost of from 5s. to 5s. 6d. per ton by drays. This cupriferous flux could then be landed in Cobar for 11s. per ton. For purposes of calculation it may be assumed that a judicious selection of Tinto and C.S.A. ores results in a kindly fluxing ore containing 30 per cent. excess of iron over that of silica, and that the copper contents of such ore mixture is 1·5 per cent., the lead and zinc contents* being negligible. It will scarcely be maintained that this is not a favourable view of the part the C.S.A. would occupy in any purely smelting campaign; the figures are simply chosen as those from which important deductions can be made. Modifications could be introduced later with accurate knowledge of bulk assays of the ore bodies.

* The lead and zinc asset is dealt with later under concentration.

Furthermore, it will be assumed that the losses of copper do not exceed ·5 of a unit, although it is a well-known fact that it would be difficult to secure a recovery exceeding 80 per cent. of copper. The former view is the more favourable assumption.

In the following notes, also, the cost of smelting a ton of neutral ore will be taken as 8s., against 6s. 6d. for the ordinary smelting costs of Great Cobar. Converting costs will also be put down as 1s. 9d. per ton, against 1s. 4d. from Great Cobar returns. The latter cost, however, is for a copper ore of 2·5 per cent. value, whereas an ore of from 6 to 10 per cent. would be more. These low figures are only possible when dealing with huge quantities in large modern furnaces. It would scarcely be possible to smelt the Occidental, Gladstone, Young Australian, and Tinto ores for such a low figure as this, because of the relatively small size of these ore bodies.

In all cases it will be considered that the production of a bisilicate slag is aimed at.

Each mine is considered separately, as it is a simple matter to consider the effect of combining two or more ores of known quantity and composition.

The Budgery.—This mine need not be taken into consideration in this discussion, because its ore reserves are small, and the management is unable at present to prove the existence of ore bodies other than those already blocked out.

The Budgerygar Mines.—The ore bodies here also are not sufficiently developed to consider them in this discussion. The case would be different if they were in proximity to the smelter. Assays of this ore by the Great Cobar, Limited, show the ore to be rich in copper in the oxidised zone, and to possess an actual excess of iron over that of silica. Freight to Cobar, approximately, 17s. 6d. per ton. Mining costs, say, £1 per ton.

[These mines have not been examined by the Writer.]

The Occidental.—Gross value of ore, as estimated by a consideration of assays and yearly returns (allowance being made for incomplete recovery by amalgamation and cyanidation), about £1 5s. per ton of ore. Ore reserves vary from 125,000 to 350,000 tons, according to the method of working to be adopted in the sulphide ore. If the narrow and richer veins only be mined, the former figure is a conservative estimate of ore reserves existing in September, 1911; if the whole width of lode be mined, 300,000 tons of ore were apparently available in September, 1911.

Classifying the Occidental ore as similar to that of the Cobar Gold in regard to silica and iron, it is evident that its silica excess is 71 per cent. Therefore, in every ton of Occidental ore there would be:

$$\frac{71}{100} \times 2{,}240 \text{ lb. silica} = 1{,}590 \text{ lb. silica.}$$

A bisilicate slag has the formula:—

$$RO + SiO_2.$$

In this case, as lime is to be neglected, the formula becomes:

$$FeO + SiO_2.$$

As the atomic weights of Fe, Si, and O are 56, 28, and 16, respectively, it is evident the ferrous silicate will contain 45·45 per cent. silica by weight, and 54·55 per cent. FeO. Consequently, the number of pounds of FeO required to form a bisilicate is:—

$$\frac{1{,}590}{1} \times \frac{54{\cdot}55 \text{ lb.}}{45{\cdot}45 \text{ lb.}} = 1{,}908 \text{ lb}$$

Therefore, the amount by weight of iron required to smelt 1 ton of Occidental ore is :—

$$\frac{1,590}{1} \times \frac{54\cdot55}{45\cdot45} \times \frac{7}{9} = 1,484 \text{ lb.}$$

(The factor $\frac{7}{9}$ is obtained from the knowledge that

$$\frac{Fe}{FeO} = \frac{56}{56+16} = \frac{56}{72} = \frac{7}{9}$$

by atomic weights.)

As the C.S.A. flux contains 30 per cent. excess iron, it is necessary to use—

$$1,484 + \frac{100 \text{ lb.}}{30 \text{ lb.}} = 4,950 \text{ lb.} = 2\cdot2 \text{ tons}$$

of the C.S.A. ore to flux 1 ton of Occidental ore, or, in other words, to make 3·2 tons of neutral ore. This, of course, is merely a rough calculation based without reference to matte requirements.

A table of approximate costs may now be constructed :—

Costs.

	£	s.	d.
Cost of mining 1 ton of Occidental ore	0	7	0
Freight of 1 ton ore to Cobar	0	1	0
Cost of 2·2 tons of C.S.A. flux, at 11s. per ton, delivered in Cobar	1	3	0
Cost of smelting 3·2 tons of neutral ore, at 8s	1	5	7
	£2	16	7

Credit.

	£	s.	d.
80 per cent. recovery of copper on 2·2 tons of C.S.A. ore, containing 1·5 per cent. copper, at 11s. per unit... ...	1	9	0
Gold values	1	5	0
	£2	14	0

As before stated, no account is here made of losses in the matte of iron, of converting nor of realisation charges. It is also evident that difficulties would be incurred in effecting a saving of the copper in such a smelting mixture.

On the other hand, the Occidental stone would be very useful to owners of basic copper ores needing siliceous ore.

An approximation to the cost of smelting may also be obtained by calculating the costs of mining and smelting of a ton of neutral ore, and then adding thereto the cost of smelting the excess of silica at 5d. or 6d. per unit, or subtracting therefrom the excess of iron above silica at 5d. or 6d. per unit. This, however, it cannot be too often repeated, is only practicable under conditions of abundant and cheap suitable fluxes and wholesale treatment under the most favourable circumstances.

Applying this principle to the case of the Occidental, we have—

Costs.

	£	s.	d.
Mining 1 ton Occidental ore	0	7	0
Smelting 1 ton of neutral ore	0	8	0
Converting 1 ton ore	0	1	9
Smelting 71 units excess silica at 5d.	1	9	7
	£2	6	4

On the same basis the C.S.A. ore is worth from 10s. to 12s. 6d. a ton for fluxing purposes to any company needing basic ores. This value would be above its metal values. See, however, Appendix IV.

Gladstone Ore.

Typical Analyses.

	A.	B.
Copper	7·47	6·00
Iron	6·69	6·18
SiO_2	73·00	79·20
Al_2O_3	1·44	·77

In these the alumina is not considered. Many engineers, however, in their first estimate of costs, would prefer to add on the alumina to the silica or acid content.

It would be advisable to take the average of these two parcels, each being apparently from 50 to 70 tons in weight. The modified analysis thus becomes :—

Copper	6·8 per cent.
Iron	6·43 ,,
SiO_2	76·00 ,,

This gives an excess of about 70 per cent. silica, and therefore the calculations for the smelting of the Occidental ore may be reproduced here. The Gladstone thus needs about 2·2 tons of C.S.A. flux (30 per cent. excess iron) to smelt 1 ton of its own ore.

Costs.

	£	s.	d.
Mining 1 ton of Gladstone ore	1	0	0
Freight 1s., and mining 10s., of 2·2 tons of C.S.A. ore to Cobar	1	4	0
Freight on 1 ton of Gladstone ore	0	1	0
Smelting 3·2 tons of neutral ore, at 8s.	1	5	6
Converting 3·2 tons of ore, at 1s. 9d.	0	5	7
	£3	16	1

Until railway connection be established, another 10s. costs must be added for freight on the two ores, bringing the total to £4 6s. per ton costs.

Credit.

	£	s.	d.
2·2 tons C.S.A. ore, containing 1·5 per cent. Cu, less 2·2 × 5· = 1·1 per cent. loss Cu, at 11s. per unit.	1	4	2
6·8 − ·5 = 6·3 units Cu, at 11s.	3	9	4
	£4	13	6

This is exclusive of any small gold and silver values present, and a profit of about 17s. per ton is here shown. Further reference to this profit will be made when considering the case of the Young Australian.

Basing the cost of treating the Gladstone ore on a penalty of 5d. for each unit excess of silica, we have :—

Costs.

	£	s.	d.
Mining 1 ton of Gladstone ore, say	1	0	0
Smelting 1 ton of neutral ore	0	8	0
Converting	0	1	9
70 units excess silica at 5d.	1	9	2
	£2	18	11

Credit.

	£	s.	d.
6·80 − ·50 units of Cu, at 11s.	£3	9	4

Young Australian.—Average assay of one lot of typical ore, about 70 tons in weight:—

Copper	8·70 per cent. (based on average yield of copper).
Iron	8·00 ,,
Insoluble	66·20 ,,
Alumina	1·50 ,,

In this case the alumina will be treated as non-existent. (See, however, Peters' "Principles," pp. 365, 398–399.)

In this charge the excess of silica over that of iron is given as 58 per cent.

The weight of silica in a ton of Young Australian oxidised ore is, therefore—

$$2,240 \times \frac{58}{100} = 1,299 \text{ lb.}$$

And in the bisilicate slag aimed at the percentage of FeO is 54·55.

Therefore the number of lb. of FeO required to make a bisilicate slag with the Young Australian ore is—

$$1,299 \times \frac{54{\cdot}55}{45{\cdot}45} = 1,559 \text{ lb.}$$

and this needs

$$1,599 \times \frac{7}{9} = 1,244 \text{ lb. Fe.}$$

The C.S.A. ore which supplies this iron is to contain about 30 per cent. excess Fe.

Therefore, to smelt 1 ton of Young Australian ore we need—

$$1,244 \times \frac{100}{30} = 4,150 \text{ lb.} = 1{\cdot}85 \text{ tons.}$$

Costs.

	£	s.	d.
Mining 1 ton of Young Australian ore, say	1	0	0
Freight on 1 ton ore to smelter	0	2	6
Mining (10s.) and freight (1s.) per ton on 1·85 tons C.S.A. ore	1	0	4
Cost of smelting 2·85 tons of neutral ore at 8s.	1	2	9
Cost of converting 2·85 tons at 1s. 9d.	0	5	0
	£3	10	7

If ordinary freight by drays be considered, these costs would be increased by 7s., or to a total of £3 17s. 7d. per ton.

Credit.

	£	s.	d.
1·85 tons of 1·5 % Cu, at 11s., 80 % recovery	1	4	4
8·70 units Cu, at 11s.	4	15	8
	£6	0	0

We might also approach the question from the consideration of the silica percentage thus:—

Costs.

	£	s.	d.
Mining 1 ton Young Australian ore	1	0	0
Smelting 1 ton ,, ...	0	8	0
Converting 1 ton 8·70 per cent. Cu ore	0	1	9
58 units excess silica at 5d.	1	4	2
	£2	13	11

Credit.

	£	s.	d.
8·7 units Cu, at 11s.	£4	15	8

In both these calculations it would appear that there is a distinct profit, but it must be remembered that some costs are represented as very slight, while others have been neglected altogether.

Thus the smelting and converting rates are, doubtless, too small, and realisation costs are not included. Moreover, let us suppose that of such ore the Young Australian has 3,000 tons in reserve, and the Gladstone has 1,250 tons of such ore as that considered under the head of the Gladstone.

Then a profit of, say, £2 per ton is made on 3,000 tons of Young Australian ore, or £6,000, and a profit of 17s. per ton is made on 1,250 tons of Gladstone ore, or £1,062—that is, a total profit of £7,062. Then, out of this we have to bear a portion of the cost of erecting the central smelter, and also secure at least a 10 per cent. return on our money. It is a matter needing careful consideration also that the present value of money must not be confused with the amount it is worth, say, ten years hence at 6 per cent. Thus, not only the price of the smelter, but the interest on the outlay involved in its construction, has to be deducted from any apparent working profits. If we assume the erection of a central smelter and its accessories at a cost of from £30,000 to £50,000, we see that a considerable amount of ore reserves is necessary to defray even this portion of the capital sunk in plant.

The acid ores of the Cobar Gold and Chesney Mines have passed under the control of the Great Cobar, Limited, because, hitherto, it has been found impracticable to work them independently at a profit. Although their metal contents have a much greater gross value per ton than the ore of the Great Cobar, nevertheless the losses in treatment were so considerable that it was found advisable to dispose of them to the company possessing the large quantity of basic cupriferous flux. An application of the methods of estimates of costs of treatments considered in this Appendix suggests that the costs of smelting Cobar Gold and Chesney ores separately would leave little or no margin of profit unless concentration before smelting be carried out. Even with concentration beforehand, it is doubtful, whether the Chesney and Cobar Gold could mine and treat their ores independently for less than £1 4s. per ton.

It is thus evident that the greatest skill would be necessary to achieve commercial success in smelting those ores which at present are not under the control of the Great Cobar, Limited.

It is, however, probable that a system of simple concentration before smelting would be a much cheaper process for the small mines than ordinary smelting. Thus the ore could be crushed with rolls and jigged to produce, say, a 15 to 20 per cent. concentrate, the tailings of which could go to regrinder, and thence to an oil-flotation plant. Phellandrene oil would probably be the best oil to use. From this flotation plant 20 to 25 per cent. concentrates might be expected. Recovery in the mill might be expected to average about 80 per cent. after commencement of flotation process.

By this or other processes the lead and zinc of the C.S.A. might perhaps be recovered. The Occidental might be worked in a large way by complete sliming and treatment with filter process (see page 144).

APPENDIX IV.

Since the appearance of Appendix III in type the mining industry at Cobar has undergone some important changes, and the conclusions set out in that Appendix may be modified to meet the present conditions. Chief among these changes may be mentioned the development of acid and basic copper ores in the eastern portion of the C.S.A ground and the proposal of the Great Cobar, Limited, to concentrate the siliceous ores of the Cobar Gold and the Great Cobar Mines before smelting them. The Chesney ore is already being concentrated.

(*a*) *C.S.A. Development.*—It is well known in the Cobar district that the typical ores of the C.S.A. and Tinto Mines are dissimilar in general appearance although they occur in adjacent blocks. Thus the eastern body of Tinto ore is characteristically pyrrhotitic and flinty, while the C.S.A. ore is pyritic in nature. Among others, Mr. C. R. Mackenzie, manager of the C.S.A., considers that the Tinto Lode passes into the C.S.A. Block, and in 1912 he was enabled practically to prove this by discovering a body of pyrrhotitic ore in the C.S.A. Block and lying east of the main pyritic bodies. This is now being followed southwards to the Tinto Lode with which it may be expected to show some intimate relationship. At the same time, siliceous copper bodies have been found in the neighbourhood of the basic pyrrhotite ore, and although the primary sulphide zone has probably not yet been reached nor the average width of these additional ore-bodies been ascertained, nevertheless, there is now some promise that the C.S.A. and Tinto ores may constitute a good cupriferous flux with which to smelt outside ores. Should the new bodies be found to possess considerable length and width, then the C.S.A. and Tinto Mines should become payable by smelting methods, especially if a scheme of concentration be adopted in the case of the more siliceous portions of the ores.

(*b*) *Concentration.*—As already stated, the Great Cobar have erected a small concentrating plant at the Chesney, and propose to erect concentrating plants at the Cobar Gold and Great Cobar Mines. The siliceous ores would be crushed, jigged, and treated by the oil-flotation process, the concentrates would go to reverberatories, while the basic ores would go direct to the water-jackets. It is thus probable that both the Chesney and Cobar Gold ores could be treated independently at a profit, although it is doubtful whether they could be treated nearly as cheaply thus as they are at present by the Great Cobar smelters. It is probable that this concentration preparatory to smelting will simply enable the Great Cobar to husband its important basic ore-bodies for smelting purposes.

With the C.S.A., Tinto, Gladstone, and Young Australian Mines it may well be that a similar method of treatment would be found to be successful. The smelter could be erected at the C S.A. or at Cobar; the copper of the acid ores could be concentrated possibly in a ratio of from 1 to 5, and the concentrates could be treated at the central furnaces.

In the Writer's opinion, however, the success of such a venture is only assured if the C.S.A. and Tinto Mines can be shown to be payable independently of such mines as the Gladstone and Young Australian, otherwise they would have to suspend operations as soon as the ore from the smaller bodies became exhausted.

By the treatment of large tonnages the costs of mining and treatment, as outlined in Appendix III, would be considerably lessened, and might even be reduced to as low a figure as £1 5s. per ton of mixed ore.

With regard to such bodies as the Gladstone and the Young Australian it would, doubtless, be possible for them to become payable as independent concerns by concentrating their ores by means of the oil-flotation process, if amenable to such treatment, and then disposing of them to smelting companies. The costs of independent smelting for these siliceous ores, in the absence of concentration processes, appear to be prohibitive under the present conditions.

APPENDIX V.

Notes on Cobar Mines for 1912.

(Extracts from Mr. Inspector Oldfield's Annual Report.)

Great Cobar.—Opened up No. 13 Level, and sank the main shaft still deeper, the intention being to continue this shaft to the 16th Level. "A noticeable feature is the vast improvement found in the Great Cobar, Nos. 12 and 13 Levels, where the ore body has become larger, wider, and better value ore, which may be considered highly favourable in view of the large movement of the ore body between Nos. 10 and 11 Levels."

"The ore body at the lowest levels has become more distinct between the siliceous and basic bodies, without having the large mullock intrusion as in the levels above."

Cobar Gold.—Very little development, but general conditions of mine highly satisfactory.

Chesney.—Sinking of Main Shaft from No. 7 to No. 8 Level, and the opening out of levels north and south at each of these points.

"It must be pointed out that large, wide, and continuous ore bodies have been proved to exist, of a highly payable nature, which can be treated by the new mill."

Occidental.—"A fair amount of development work has been carried out at Nos. 4 and 5 Levels on the eastern narrow veins, showing good grade ore, especially at the northern end . . . . The prospects of this mine are very encouraging for the current year, and I understand a big development policy is intended by the owners.

"The plant has been increased by the addition of a unit of regrinding and slime treatment machinery."

Young Australia Cobar Copper, Ltd.—This mine is let on a five years' tribute agreement. A fair amount of development was carried out by the tribute party "on the 350 ft. level, and connecting up to the 250 ft. level, exposing a fair sized vein of copper ore under foot."

Queen Bee Copper.—"A fair amount of development work has been done in the lower levels."

Gladstone.—This mine has been idle during the year.

Great Cobar North.—The shaft is being sunk from the 1,500 to the 1,600 ft. level, and the proposal is to open out for the purpose of cross-cutting to the lode. A large hoisting engine has been installed.

C.S.A. Mines.—"2,519 tons of lead ore were raised and sent to Cockle Creek for treatment for a return of £14,185. A considerable amount of driving on ore through this large deposit was done during the year (414 ft.) Further fine deposits of lead carbonate ore were disclosed, some of which showed native silver of very high value."

"It is interesting to note that the lead ore has lately carried much higher values in silver. This mine has made a considerable profit on the year's operations, owing to the satisfactory high price of lead.

"During the year the Company has carried out 574 ft. of diamond drilling with most encouraging results from the 660 ft. level, East cross-cut. The drill has passed through three distinct ore bodies (copper), being 100, 15, and 10 ft.

respectively, of mostly basic ore, which will probably go from 2 to 3 per cent. of copper. This is extremely encouraging, and promises to be one of the future big things in the Cobar district."

This report of the C.S.A., by Mr. Inspector Oldfield, is highly encouraging, and if the bodies have an average size and value as indicated by boring, the C.S.A. Mine may be expected soon to have a large smelting plant of its own. It has long been recognised that if the copper contents of the C.S.A., together with the Tinto ore deposits, could be brought up to about 2·5 per cent., they should be payable to smelt in a large way.

Tonnages and Yields of Mines at Cobar for 1912.

Great Cobar.—Ore treated, 255,993 tons.

Cobar Gold.—Ore treated, 50,906 tons.

Chesney.—Ore treated, 23,544 tons.

Peak Gold.—Ore treated, 1,432 tons.

From this ore the return was 6,650 tons copper, 39,072 oz. gold, and 202,330 oz. of silver, for a total value of £575,521, an increase of £117,311.

Occidental.—Ore treated, 36,827 tons, for a return of 11,893 oz. of gold, valued at £48,231.

Young Australia.—730 tons ore sold for £2,396.

Silver Peak.—188 tons ore sold for £1,329.

Queen Bee Copper.—1,808 tons ore produced 103 tons copper, valued at £7,725.

C.S.A.—2,519 tons lead ore raised, for a return of £14,185.

Tinto Copper.—60 tons ore raised, expected to yield 8 per cent. copper.

Additional Notes on the C.S.A. Mine.

Mr. A. T. Brown, Consulting Engineer for the C.S.A., has supplied the following information dealing with this property. The results are highly encouraging.

" From the large secondary ore body at the 450-foot level, about 3,000 tons were sent away, averaging over 30 per cent. lead, about 3 oz. silver, and 2 dwt. gold ; 19 tons lead ore averaged about 450 oz. silver per ton.

Description of Bores.

" *No.* 1 *Bore* put in 414 feet to the east from the cross-cut on the 660-foot level. Passed through 107 feet of pyritic ore in belts from 10 to 36 feet in width.

" Assays of the 36 feet wide belt :—

" Average : 1·65 copper, 3 grs. gold, ·5 oz. silver. The last 15 feet in this bore yielded an average of 2·02 per cent. copper, 3 grs. gold, ·5 oz. silver, 38·4 per cent. sulphur, 11·4 per cent. insoluble, 38·8 per cent. iron, 2·8 per cent. zinc.

" The belt from 265 to 280 feet in the bore averaged ·87 per cent. copper, 3 grs. gold, ·8 oz. silver, 39·5 per cent. sulphur, 6·4 per cent. insoluble, 32·4 per cent. iron, and 11·5 per cent. zinc.

"Two other bodies, 10 and 11 feet in width respectively, yielded on assay from ·3 to ·48 per cent. copper, 3 grs. gold, ·1 to ·5 oz. silver, 40·6 to 42·1 per cent. sulphur, 8·2 to 12·6 per cent. insoluble, 26 to 35 per cent. iron, and 4 to 21 per cent. zinc.

"Zinc occurred through the core in bands.

"*No.* 2 *Bore* put out 300 feet east from No. 7 cross-cut at the 560-foot level. No complete assays have been made of this core.

"Several belts of siliceous ore were cut averaging about 2 per cent. copper, and a large portion of the bore passed through schists showing a fair amount of pyrites and pyrrhotite.

"*No.* 3 *Bore* put out 240 feet west from Western Cross-cut off South Drive at the 560-foot level.

"Passed through a solid body of clean pyrites 38 feet in width. In addition to this the bore passed through 4 feet of siliceous ore averaging about 3 per cent. copper.

No. 4 *Bore.*—This bore was started from the end of the main East Crosscut at the 560-foot level. This bore will pass vertically over No. 1 Bore."

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